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THE NOVEMBER SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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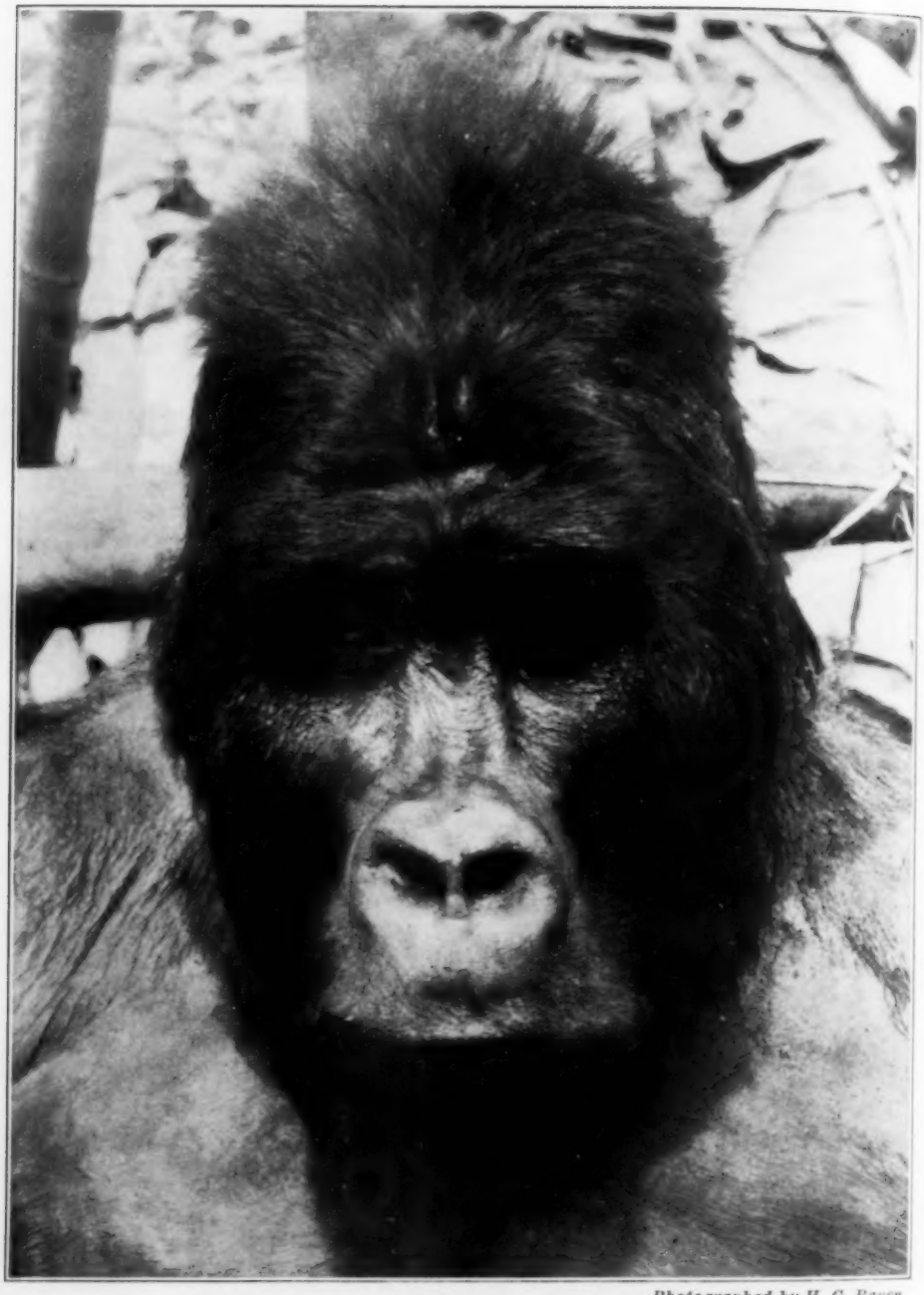


Photographed by H. C. Raven

THE DEAN OF THE ANTHROPOIDS

HEAD OF *Gorilla beringei*, MALE; SHOT BY DR. H. C. RAVEN AT TSCHIBINDA IN THE MOUNTAINS WEST OF LAKE KIVU.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1935

IN QUEST OF GORILLAS[1]

I. ON OUR WAY TO GORILLA-LAND

By Dr. WILLIAM KING GREGORY

CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY; PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

At the College of Physicians and Surgeons of Columbia University Professor Dudley J. Morton has long been studying the queer and often sad results of our being made-over quadrupeds. After countless ages of quadrupedal life our ancestors somehow learned to walk on their hind legs; but in so doing they necessarily concentrated their entire weight upon their hind feet. To this added burden even our own feet have not yet become perfectly adapted, as shown by their frequent breakdown. In addition to this we have forced our feet into cages, called shoes, which at best have deprived us of the leathery soles of our ancestors and at worst have transformed our feet into horrible monstrosities. Professor Morton, from his studies of orthopedic problems, found that a great deal of both theoretical and practical value could be learned about the mechanism of the human foot by viewing it in the light of its long evolutionary history. It had been shown by others that nature in the feet of many animals still living has preserved various stages illustrating the transformation of a quadrupedal, ground-dwelling type of foot first into the more or less hand-like feet of the monkeys and apes and finally into the peculiarly modified foot of man. It remained for Professor Morton, however, to make successful application of such past evolutionary data to the interpretation of the mechanism of the present evolutionary stage of the foot in the American variety of *Homo sapiens*. For further progress in this work he needed to study the anatomy of the feet of ordinary mammals, of monkeys, gibbons, chimpanzees, orangs, gorillas, as well as of primitive human feet, unspoiled by the wearing of shoes. Thus when he turned to us in the Department of Comparative Anatomy of the American Museum of Natural History for material, we could give him almost everything that he wanted for dissection, with the important exception of adult gorillas and primitive unshod humans. But in this department our associate curator, Henry C. Raven, was well fitted by long experience and training in field and laboratory to go after the material that was needed.

So, to make a very long story short, Professor Morton and his colleagues at the Medical Center secured the personal and official backing of President Butler, who in turn brought it about that Columbia University provided the funds, while the American Museum of Natural History supplied the leader of the expedition, which was thus sent to tropical

[1] The story of an expedition sent by Columbia University and The American Museum of Natural History to the Belgian Congo and the French Cameroon, Africa, in 1929 and 1930.

Africa under the joint auspices of the university and the museum.

As my three colleagues will be so often mentioned in the following pages, it may be well to begin with a brief characterization of each of them, even at the risk of incurring their modest expostulations and perhaps reprisals when their individual stories of the expedition come to be written.

Mr. Raven, the leader of the expedition, is well known among museum circles for his extensive zoological explorations and collections in Borneo, Celebes, Australia, Greenland and Africa. His field studies on the natural history of many mammals have been happily supplemented by his sound anatomical investigations in the laboratory. He is a rather calm and deliberate person, one who answers questions only after a certain pause, which might sometimes irritate persons of the Gallic temperament. "*Festina lente*" and "Don't shoot till you see the whites of their eyes" might well be his favorite maxims. "It's dogged as does it" might also be appropriate. In the forest he is remarkably sure where he is, no matter how many twists and turns the quarry may have made, and when the critical moment comes he is uncommonly quick on the trigger. He delights in mastering the cussedness of inanimate objects, such as refractory mechanisms, and loves carpentry, cabinet-making and the sailing of cranky boats. Native technique, as of making houses and devising traps and snares, appeals strongly to him and he can live on locusts and wild honey if necessary. He finds that, as a rule, Dyak head-hunters, Malay pirates, Eskimo seal hunters, Australian trackers and African ex-cannibals have learned many valuable ways of adapting their environment to their needs and no false sense of superiority prevents him from learning from them. Upon him fell the major responsibility of laying out the route of the expedition, obtaining reliable estimates of cost, purchasing the field equipment and getting the gorillas.

The senior naturalist of the expedition was Professor J. H. McGregor. Among the main assets of the expedition was his more than encyclopedic and practical knowledge of zoology, embryology, anatomy and photography. Scarcely less important in sustaining our morale were his instantaneous and witty retorts and his extensive and delectable stock of Scotch and other stories. "Happiness in every box" might have been his motto, and many were the amusements, tricks and presents which he contrived to bestow upon the jolly black children that played around our camps in tropical Africa.

Dr. Earl T. Engle, associate professor of anatomy at Columbia University, the third member of our expedition, is a big athletic blond with a broad smile and a friendly way with dogs and humans. He is quick, incisive, accurate, original and dynamic. On our long journey across Africa the only thing that really peeved him was enforced idleness, during our many seemingly interminable waits for porters, customs officials, camions, trains, steamboats, etc. He was especially interested not only in comparative anatomy and zoology, but in the medical equipment of the Belgian Congo and was active in securing observations, photographs, footprints, etc., and records of African natives.

The main reason why I too was a member of this expedition was that I had firmly taken it for granted that I was going to be, and fortunately it did not occur to any one to question it. At the Museum of Natural History we had had some lively discussions on the origin of man, Professor Osborn stressing man's immensely ancient lineage and his alleged freedom from the taint of the "bar sinister of ape ancestry," while I had defended the right of the chimpanzee and the gorilla to be recognized as our poor relations and as mute witnesses of

Photograph by H. C. Raven

THE PATHWAY TO AFRICA

BREAKWATER AT PORT SAID, LEADING TO SUEZ CANAL; STATUE OF DE LESSEPS AT THE FAR END.

our former low estate. I had published various papers, chiefly based on the study of the skulls, teeth and skeletons of fossil and living members of the order of Primates, but I was keen to see for myself how man's nearest living relatives lived in their native forests and to acquire some first-hand knowledge of the teeming life of present and past ages in Africa. I was also especially interested in the evolution of fishes and hoped to see some of the most famous African species in their own environment.

Thus we four, shortly before midnight on May 29, 1929, found ourselves in the smoking-room of the *Aquitania*, bound for London *en route* for Dar-es-Salaam on the east coast of Africa. Africa, however, was still a long way off and our immediate anxiety was to obtain permits from the Belgian authorities to shoot one or more adult male and female specimens of the mountain gorilla, which lives in the mountains and highlands east of the Congo River, and then to obtain permission from the French authorities to secure an equal number of the lowland species from the region north of the Gaboon in western Africa. No anatomical laboratory in the world, so far as we knew, had adequate material of either species of gorilla. A few young specimens from zoological parks had been dissected, but the adult anatomy was but poorly known.

Soon after arriving in London we went to pay our respects to His Excellency, M. Émile de Marchienne, Baron de Cartier, who was then the Belgian ambassador to the Court of Saint James but who had formerly been the Belgian ambassador to Washington. The baron had encouraged and aided the late Carl Akeley, of the American Museum of Natural History, whose report to King Albert had assisted the latter in his plan to establish the Pare National Albert in the mountains of the Belgian Congo, as a perpetual sanctuary for the gorillas and other wild life there. Baron de Cartier explained to us that from his friendship and close association with Carl Akeley he had acquired Akeley's determination to save the gorilla from extinction. He had, in fact, become an ardent conservationist to the point of being unwilling to allow a single gorilla to be killed even for scientific purposes. He well understood the value of studies on the anatomy of the gorilla, but if we were allowed to take two specimens, or even one, would not our scientific reports lead other specialists to question our conclusions, at least at certain points, and would not they then clamor for more sacrifices? This was a home-thrust that

we had not expected and with sinking hearts we replied that we were not, of course, requesting any violation of the sanctuary of the Parc National Albert; we were asking for permission to obtain one or two gorillas somewhere else in the vast territory of the Belgian Congo. We said also that great numbers of gorilla skins and skulls had been taken because it was far easier to do this than to preserve every bit of the precious body for anatomical study; but that it was our object to secure this priceless anatomical data before all the gorillas outside the Parc National should be destroyed by natives and white settlers. The baron insisted that it was the intention of King Albert's government to enforce the laws for the protection of the gorillas. At last, however, he consented to give us letters of introduction so that we could explain our mission to the proper authorities in Brussels.

While in London, Brussels and Paris we were extremely busy in completing our equipment, obtaining letters of introduction, maps, information about routes, etc., but I, who had less of this business than the others, had time to make notes in the several universities and museums of natural history. All these places contained a wealth of material bearing on our special interests, the comparative anatomy and evolution of vertebrate animals, including man. For example, at the British Museum (Natural History) in London I again examined the fossil jaw and teeth of *Dryopithecus fontani*, an extinct ape from the Miocene epoch of Spain, described by Sir Arthur Smith Woodward. This highly interesting form was rather closely related to the ancestors of the gorilla and, together with other similar material from France, Germany, Austria and India, it proves that the existing gorillas, chimpanzees and orangs are merely the widely scattered relicts of an older anthropoid group which was formerly very widespread over the semi-tropical zone of the Eastern Hemisphere. In this same *Dryopithecus* jaw each lower molar tooth has three principal cusps on the outer side and two on the inner side, exactly the same number as in the lower molars of primitive races of men. Moreover, the bases of the cusps are separated from each other by a definite system of grooves, each of which clearly corresponds to a similarly placed groove in primitive human molars. These and hundreds of other striking resemblances between man and the anthropoid apes can hardly be explained away as coincidences or accidental resemblances. There is, in fact, a pervasive resemblance between the entire anatomy of man and that of the gorilla and the chimpanzee, accompanied by many differences; the latter have presumably been acquired after the separation of man from the basal anthropoid stock.

At University College, London, Professor J. P. Hill showed us some of his beautiful microscopic sections of the wall of the uterus and of the membranes connecting the young with the mother in the lemurs, the tarsier, South American monkeys, Old World monkeys, apes and man. He has shown that the foetal membranes of man are almost identical with those of the gorilla and the chimpanzee. Thus the leading English authorities all support the view held by Sir Arthur Keith, Sir Grafton Elliot Smith, Professor Adolph Schultz, of Johns Hopkins University, and others, including myself, that the ancestry of man merges with that of the anthropoids before descending to lower levels of the family tree of the primates.

At the Royal College of Surgeons we had the privilege of examining some of the beautiful anatomical preparations upon which Sir Arthur Keith based his presidential address before the British Association meeting in 1928 on "The Origin and Evolution of Man." No better statement of the present status of the problem of man's relationships to the

existing anthropoids could be recommended to the general reader.

At the home of Miss Alyse Cunningham in London we had the pleasure of hearing about her adventures on the west coast of Africa, where she and her nephew, Captain Penny, had obtained a pigmy hippopotamus and a baby gorilla. Some of the conditions she had encountered—swarms of mosquitoes, biting bugs, venomous centipedes, burning days and steaming nights—did not sound very alluring to the prospective explorers.

At the Zoological Gardens in London we found a splendid collection of primates, including chimpanzees and orang-utans, all in excellent condition. Their deserved popularity with the crowds confirmed us in thinking that our own humble efforts to teach the "Darwinian theory" of man's origin were far surpassed by the unconscious teaching of the apes themselves, whose all too human antics were heartily applauded.

At this spot I heard a little old woman say very firmly to her friend, as they both gazed at a large chimpanzee, "Oh, *we're* not re-*lit*ed to 'im"; as if to deny any claim that " 'E's relited to us."

At the beautiful Aquarium near-by we

PHARAOH'S SAILS *Photograph by H. C. Raven*

had the privilege of seeing living specimens of some of the most famous African fishes, in whose anatomy and evolutionary history we had long been interested. Here were many "living fossils" surviving from earlier ages of the earth's history, along with the very latest modes in body-form and decorations in the swarming African fish world.

When we arrived in Brussels we were met at the station by Dr. J. M. Derscheid, the secretary of the Belgian "Office for the Protection of Nature." This is a remarkably efficient and compact organization for the encouragement of national and international movements for the protection of the fauna and flora in all countries of the world. This office keeps up to date a complete file and transcript of all laws dealing with the protection of game or other natural resources and it sends accurate information on such matters to those engaged in the struggle for the conservation of wild life. Dr. Derscheid was especially interested in the protection of the gorilla, for he had been Akeley's companion in the field and had himself made a close-up study and census of the gorilla population of the Parc National Albert. But, a zoologist himself, he also knew the need for well-preserved material for the study of the anatomy of the adult gorilla. Accordingly he gave his personal endorsement to our request to obtain two adult specimens in the Belgian Congo; he introduced us to various high officials of the government, entertained us handsomely at his own residence and gave us maps and much information of great value. Thus was continued a long record of friendship and generosity to the American Museum of Natural History on the part of the Belgian government and its officials, who had at various times made it possible for Lang and Chapin, Akeley, Clark and others to secure splendid collections for the museum from the Belgian Congo.

At the Museum of the Belgian Congo at Tervueren, a suburb of Brussels, we saw fine examples of the native sculpture, together with mounted groups representing different phases of the life of the people. Of even greater interest to me was the large relief map showing the topography and geology of the Belgian Congo. From this I made notes which were useful later when we were traveling across Africa.

In Paris the *Musée d'Histoire naturelle* was my special mecca, as it contains priceless material illustrating the history of life on the earth. There I examined two other jaws of the fossil ape *Dryopithecus,* which, as already noted, appears to stand in or near the line of ancestry of the gorilla, chimpanzee and man. Seven months later, on my return to Paris, the eminent curator of the fossil collections, Professor Marcellin Boule, showed me among other treasures the foot of a fossil man of the Neanderthal species, which has the great toe markedly divergent, recalling to some extent the condition in the gorilla and the chimpanzee.

At the *Jardin des Plantes* we stood in front of the house where the illustrious Lamarck had lived—he who almost a century before Darwin boldly proclaimed that proud man was essentially a tailless ape that had acquired a large brain and learned to walk upright!

In the menagerie near-by we found a very engaging family of orang-utans. The mother orang conceived the bright idea of putting an empty pan on top of her head and was so much pleased with herself that she laughed visibly, though not audibly except for a sort of panting and hissing sound. A very young gorilla in the same collection was an insane-looking creature who illustrated some of the worst possible results of keeping a young gorilla in a cage without companions or playthings.

In Paris we encountered quite unexpected and dangerous opposition to our request for permission to secure gorillas

from the French Congo. Certain officials had taken offense at what they considered to be the unwarranted interference of the New York Zoological Society in protesting against the selling of baby gorillas by animal dealers. Nevertheless, largely through the kind endorsement of our French and Belgian scientific colleagues, our request was finally forwarded to M. Antonetti, governor-general of the French Congo, who many months later received us with great courtesy and gave us letters of introduction to M. Marchand, governor of the French Cameroon, where Mr. Raven finally secured the desired specimens of the West African gorilla.

At last all our preparations were complete and it was with no little relief that we boarded the night express from Paris to Marseilles. At Marseilles we paid a visit to the *Musée Longchamps*, a fine building at the top of a steep hill; in front of it is a great semicircular stone structure with long flights of steps, fountains, huge arches and abundant sculpture. But this imperial-looking monument stands in wide contrast to the more or less neglected museum at the summit. In its deserted halls interminable rows of ancient stuffed animals and hundreds of jars of alcoholic fishes (some of them very rare and famous species which we had never before seen) stand as evidence of the diligence and enthusiasm of the founder and his immediate successors. But now there are no signs of life about the museum, through which we were shown by an elderly porter who let us in through the basement. The zoological park near the museum was hot and dusty and very few visitors were present. Apparently there is not much popular interest in natural history in Marseilles at the present time.

On June twentieth we went down to the wharf, climbed up the black side of the steamer *Chambord* and began to feel that at last we were really on our way to Africa. All our numerous boxes, bedrolls and other camp equipment were safely stowed in the hold and we began to look around the vessel that was to be our home for the next nineteen days.

For a long time I watched the crew taking on the cargo. Here were real Africans at last, instead of the Harlem blend familiar to me, and looking just as if they had walked out of the pages of Sir Harry Johnston's books on the peoples of Africa. Nearly all of them were vociferating loudly and constantly; this state, I soon learned, was the normal one for adult male Africans. After sunset the hubbub subsided for a while. A pious black Moslem spread his mat and prostrated himself toward the east. Various weird-looking hybrids came out of their holes below to sniff the evening breeze. To me the steerage is nearly always more interesting than the cabin, with the added advantage that black and brown deck passengers apparently do not resent being stared at, not even when making their simple arrangements for sleeping on the soft side of the forward hatch.

Just outside our cabin there was a passageway along which members of the crew passed back and forth at all hours of the day and night. Incredibly gruff and guttural voices assailed our eardrums and profaned the stillness of the calm night. Thinking out loud (if thinking is not too complimentary a term) began long before dawn and continued with but few interruptions until heavy sleep slowed down the vocal apparatus. But as there were always fresh relays coming and going, it was not the individual that counted so much as the mass effect, which was enough to ruin the disposition of an ivory Buddha. And if an hour before dawn there was a brief lull, the gang of deck-swabbers soon struck up their five o'clock chorus of scratching brooms, hissing and gurgling water streams, banging pails and raucous voices.

Nor did the pallid passenger get much

Photograph by J. H. McGregor

TWO DJIBOUTI BOYS ON THE DECK OF THE *CHAMBORD*

WHO SCALED THE SIDES OF THE BOAT AFTER SWIMMING MANY FEET UNDER WATER TO SEIZE COINS THROWN BY MEMBERS OF THE EXPEDITION.

respite during the day. If he tried to forget his troubles by writing, the ship's band soon drove him away from the smoking-room, where he had picked what looked like a less riotous corner. Up forward three or four morons were always slamming down heavy rubber disks on a resounding-board, applauding every hit or miss with clamorous mirth; tiny boys and girls romped and screamed, French and Belgian ladies exchanged lively barrages of articulate speech. At mid-deck the second-class passengers were driving a scratchy phonograph. The cabin down below, besides being frightfully hot, was within the sound of noisy black imps that were forever jabbering over their tasks.

One of the chief events of a long day in the Mediterranean and Red Seas was hustling down to an early continental breakfast in one's pyjamas. Only one

member of the expedition ever succeeded in overcoming his inhibitions (if he ever had any) enough to conform to this custom. The rest of us were too much bound by the tradition that pyjamas of varied hues and stripes were made only to sleep in; and frankly we lacked courage to appear in public *en déshabillé*. It was surprising, however, how spruce and well tailored some of our fellow passengers looked in these garments. One wondered if they had put them on only when they got up. At a *petit déjeuner aux pyjamas* a gentleman would, of course, never venture more than a discreet and furtive glance at the ladies, as they appeared one by one on the grand stairway; if the truth were told, one furtive glance was too often enough. Then, after conquering one's own violently anti-social feelings, if one attempted a feeble pleasantry for the benefit of the lone Englishman across the table, his impassive rejoinder made one realize that after such a night and at such an abominably early hour even the "autocrat of the breakfast table" would have found it seemly to refrain.

But just as sickness and adversity turn some men toward religion, discomfort often makes it easier for some to seek release in work. My lethargic conscience reminded me of a series of three articles on "Basic Patents of Evolution," which I had long since solemnly promised to write. Accordingly I set to work each day after breakfast and, with much time off for slothful ease, found the nineteen-day voyage only just long enough to complete my stint.

After a few days in the Mediterranean we went through the Strait of Messina and with our field-glasses studied the passing panorama of buff and gray mountains and the shore, dotted with flat-roofed houses. The serrate peaks gave evidence that the whole country was largely made up of volcanic ash and indeed one mountain especially looked like the core of an ancient volcano. Now a volcanic country is often an unstable country, sinking and rising above the sea-level over long ages. This brought to mind the conclusion of paleontologists that there was once a land-bridge from north Africa through Malta, Sicily and Italy, which permitted the ancient Italian elephants to invade Africa, leaving the extinct pigmy elephants of Malta on the road. Had the ancestors of the chimpanzee and gorilla reached Africa over the same route, or had they come across some old bridge near Gibraltar, coming down from Spain and working their way along the west coast, thus reaching the Congo Basin by a roundabout route?[2]

After many days we saw at last a long thin line stretching out to meet us from Egypt. It was the gigantic stone breakwater leading to the Suez Canal; soon a heroic statue of De Lesseps welcomed us to this broad highway of East and West. And what a procession it was that passed us: first, a broad-beamed ship from the Dutch East Indies, with flat-faced Malay ex-pirates squinting cheerily over the rails; next a dingy Portuguese collier; then an immaculate Scandinavian with two rosy-cheeked ladies as the only visible passengers. Quite naturally one thought of mighty seas and romantic shipwrecks, of the castellated sea-caves off the Tasmanian coast, of Cocos Island and its pirate's harbor.

After coming into the harbor of Port Said we picked our way among the crowding ships and stopped a little way from the wharf, with which we made contact over a row of pontoon floats. The Egyptian warehouses and other

[2] Evidence against both these possibilities has since been discovered by Mr. Hopwood of the British Museum (Natural History), who has found fossil jaws and teeth of primitive chimpanzees in east Africa. This makes it appear probable that the anthropoid apes came in from the northeast, perhaps through Arabia, along with many other species of forest-living mammals and birds of Eurasiatic origin.

Photograph by J. H. McGregor

BOYS IN THE SANDY STREETS OF DJIBOUTI

THE VILLAGE IS UNBELIEVABLY HOT AND DRY, AND BARE OF VEGETATION.

buildings near-by looked ample and dignified because they had very high stories and high narrow windows. We were then boarded by haughty Egyptian officials and their black assistants in red fezzes and flowing white robes. We seized the opportunity to go ashore to do some shopping and I bought an excellent pith helmet at a very reasonable price.

Late that night from a huge coal barge along our side a line of human ants swarms up the steep planks, bearing in baskets heavy loads of coal which they cast down into our bunkers. Shafts of white light from the ship pierce the swirling clouds of black dust and glint from the coal-coated bodies of the toiling athletes. The vocal alarms of our crew are as nothing to the pandemonium raised by these devils with their confused shouts and chanteys. For hours they descend into the pit and reascend; their

huge chief, like the mighty prince of darkness, rages and bellows above them all.

By daylight we are slipping gently along the canal, at first past fields and grassy banks.

We pass a craft with high curved prow and slanting sail; as when Pharaoh's ships went forth in search of gold and frankincense.

Then come salt marshes, stretching interminably; upon them is the abomination of desolation.

Sand dunes and ever more sand dunes; a lone dromedary patiently crops the withered roots.

A hissing locomotive and its train rattles past us; it pours forth great rolls of smoke and shatters the stillness and peace of the desert.

Twisted strands of rusty barbed wire stretch across the sand; old snares where men's bodies were caught during the war in the desert.

In the distance an immense pylon rears itself high above the plain; as we drift by we pay a silent tribute to the memory of those who fell defending the canal.

We stop; ships pass us, one by one; we go on in silence.

The end of the canal; a monument with a fierce lion guards the highway of the nations.

We go up out of Egypt into the Red Sea; but for us no wonders are shown, where once Pharaoh and his mighty hosts were swallowed up.

A hot wind blows upon us as from a fiery furnace; we wilt, but our complaints avail not.

The sands of the desert rain down upon us; they fall alike upon the just and the unjust. The land is far away, yet are we covered with dust like weary travelers. The sun is hidden by the yellow fog. The sea is leaden, yea, it gleams like ancient silver.

In vain the musicians sound the loud timbrel and the harp; we rally not at the blaring of the trumpet.

The heathen grind the noise-box; they disquiet others but bring unto themselves no peace.

They that smite the sackbut and the dulcimer insult the ears of the righteous; but no man rises up to curb them.

Women pant for the water brooks; the thirst of men is not assuaged by cool wine.

For the desert afflicts us in the night season; and by day its wrath lies heavily upon us.

Rough Eritrea now blows her hot breath against the sail, warning the mariner away from her hostile shore. But we sail on in the black ship.

Then Djibuti, where in the smooth harbor comely boys, black as to skin but of noble mien, befitting the offspring of Hamitic warriors, dive with glad cries into the dark blue sea; and they, swimming downward, seize the coins thrown from the many-decked ship; as when a flock of fleet-winged marine birds contend for the small fish, after having dived for them; and great is the clamor thereof.

We sail away and the cool south wind blows upon us; we cross the equatorial line, while foolish mummers profane the ancient Neptunian rites.

Many nights pass, while the Southern Cross climbs higher in the sky. Then one day Mombasa's harbor opens. "Africa, we are here."

THE RAREST OF THE OCEAN SUNFISHES

By EUGENE W. GUDGER and SAMUEL M. MacDONALD
AMERICAN MUSEUM OF NATURAL HISTORY WALLINGFORD, CONNECTICUT

INTRODUCTION

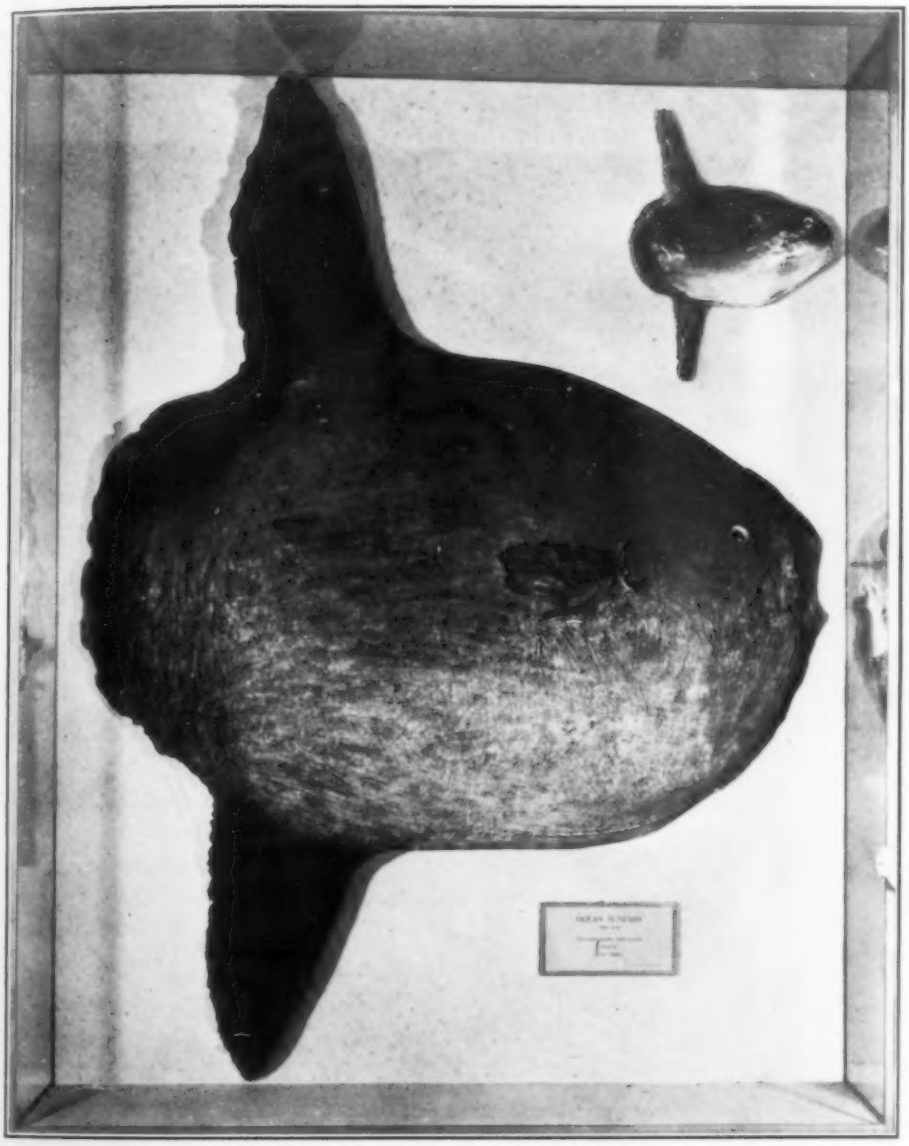
THE sunfishes, whether of fresh- or salt-water, are all, as their common name signifies, short and deep-bodied fishes. The fresh-water forms are probably known to most readers of this journal, not so, however, the marine fishes. The fresh-water sunfishes, while having bodies deep in proportion to their length, have all the fins that fishes have and have true fish-tails. Not so the marine forms which make up the family Molidae (Latin *mola*, a mill). The millstone-shaped fishes lack the pelvic fins and have the whole hinder part of the body, that behind the dorsal and anal fins, *i.e.*, the tail proper, so reduced, so telescoped, that the dorsal, caudal and anal fins are brought together so closely that one can with difficulty say where the dorsal leaves off and the caudal begins, and where this ceases and the anal begins—as the reader may see in Fig. 1. Further, the caudal fin is reduced to a mere rudimentary stump—least so, however, in the form (*Masturus*) which we are going to consider. As we shall see, the tail in this form is more extraordinary than in either of the other genera.

The ocean sunfishes are divided into three genera—each containing but one commonly accepted species. In order to make clear the relationship of the three genera to each other, it will be necessary to figure and very briefly describe the first and second kinds—the third, our fish, will be fully described with many figures further on.

The commonest and longest known of the ocean sunfishes is the round-tailed form, in which the tail and caudal fin are reduced to a mere rounded stump. This fish is commonly known as *Mola* (*Orthagoriscus*) *mola* (*rotunda*). These formidable names are interesting, as a trip to the dictionary will show. Three of these names are given to the fish because it is round, as may be seen in Fig. 1—a photograph of mounted specimens in the American Museum. The word *Orthagoriscus* means a sucking pig and was applied to this fish because of its bulky body, slightly protruding pig-like mouth, and of the allegation that it grunts like a pig. It was known to the Romans and was first figured and scientifically described in 1554 by two of the "Fathers of Ichthyology"—Rondelet, a French doctor, and Salviani, a Roman physician.

The pointed-tailed ocean sunfish is surely often confused with the round-tailed form, but neither of them is likely to be mistaken for the peculiar oblong or truncate fish portrayed in Fig. 2. Here the oblong, narrow body and the obliquely cut tail definitely mark it off from the other forms. However, although *Ranzania truncata* lacks a tail, it does have something of a tail-fin composed of fin-rays enclosed in a membrane. Furthermore, this form is small in size compared with the others. A glance at Fig. 2 makes clear the significance of its specific name. Its "front" name was given in honor of the Italian naturalist, Ranzani, who published on ocean sunfishes about a hundred years ago. The fish was first figured by another Italian naturalist, Aldrovandi, in 1613.

Having made clear the curious and abnormal forms of two members of this family, we are now ready to introduce our readers to what is seemingly the rarest and certainly the least known of the millstone-shaped fishes. This form is ichthyologically known as *Masturus lanceolatus*, and of it there are but 17

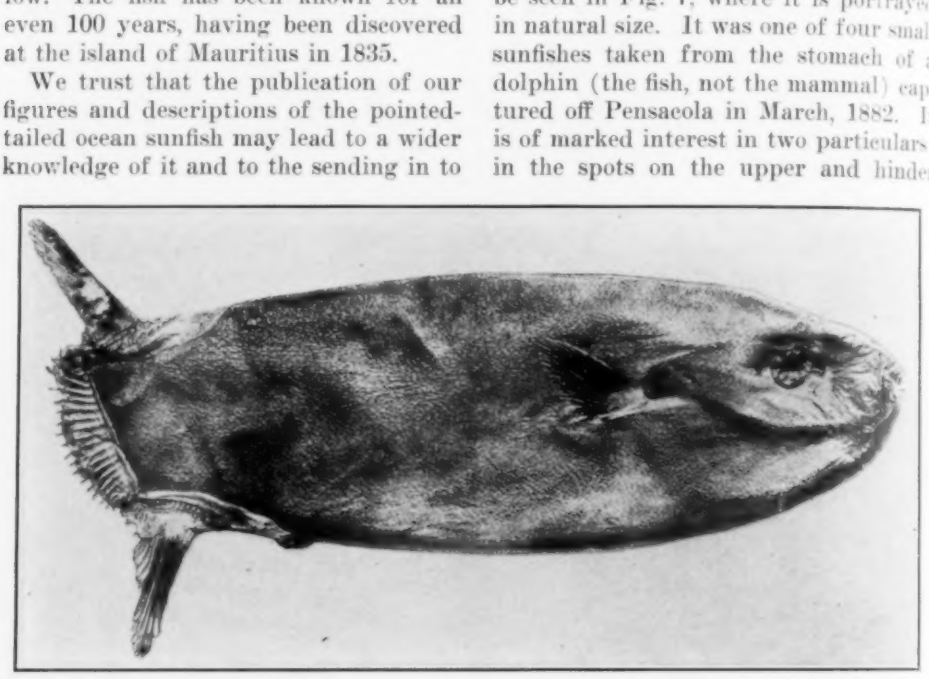


Photograph from American Museum

FIG. 1. THE ROUND-TAILED OCEAN SUNFISH, *MOLA MOLA*
MOUNTED SPECIMENS OF ADULT AND YOUNG IN THE AMERICAN MUSEUM.

specimens on record at this writing. These cognomina are interesting as their derivations show—Anglo-Saxon *maest*, a mast; + Greek *ura*, tail: Latin, *lanceolatus*, a little lance. These redundant names emphasize the curious pointed tail seen in the numerous figures to follow. The fish has been known for an even 100 years, having been discovered at the island of Mauritius in 1835.

We trust that the publication of our figures and descriptions of the pointed-tailed ocean sunfish may lead to a wider knowledge of it and to the sending in to the American Museum of other photographs and accounts of its occurrence on our coast and elsewhere.



After Steenstrup and Lütken, 1898

FIG. 2. THE TRUNCATE-TAILED SUNFISH, *RANZANIA TRUNCATA*
CONTRAST THE OBLONG BODY OF THIS FISH WITH THE ROUND BODY OF *Mola mola* IN FIG. 1.

PUBLISHED RECORDS OF THE POINTED-TAILED SUNFISH IN FLORIDA WATERS

In introducing this fish to our readers, there are first to be presented three published but little noticed accounts and figures of this fish in the coastal waters of the peninsular state. Next, accounts of new and numerous specimens will be set forth with illustrations from photographs.

YOUNG SPECIMENS ON THE WEST COAST

Off Pensacola: This chronological account very fortunately begins with the figure and brief story of a baby specimen. For this record we must go back to 1889.[1] How little this fishlet was may be seen in Fig. 7, where it is portrayed in natural size. It was one of four small sunfishes taken from the stomach of a dolphin (the fish, not the mammal) captured off Pensacola in March, 1882. It is of marked interest in two particulars: in the spots on the upper and hinder parts of the body—forerunners of what are found on the fresh-caught adult; and even more interesting is the whiplash composed of three elongated rays coming out just above the center of the caudal fin. This is a characteristic feature of the tail of all the young of this form, and is a prognostication of what is found in the tails of all adults.

These most interesting little fishes are preserved in the collections of the Civic Museum of Natural History of Genoa. They vary in size from about 1½ to 2

[1] Described by A. Perugia in *Annali Museo Civico Storia Naturale Genova.*

inches long—not counting the whiplash, which was found to grow progressively shorter in the larger ones.

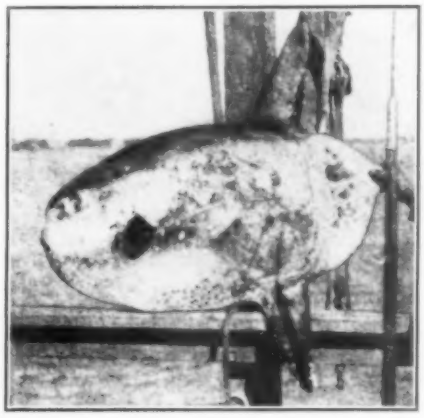
Adults on the East Coast

Heretofore adult forms have been as few and far between as have the young ones. But two grown fish from these waters have ever been recorded (one of them under a wrong name). These will be noted and then there will be listed two old museum specimens which have for long years remained unknown and unrecorded—in part at least because wrongly labelled. Lastly, four new nondescript fish will be described and figured from the finest photographs ever made of the pointed-tailed ocean sunfish.

At Palm Beach: The first record of such an east coast fish is found in the publication in 1918[2] of a figure of a specimen captured at Palm Beach in that year. This figure, which is erroneously labelled *Mola mola*, is of a *Masturus*, as may be seen in Fig. 3. It is unfortunate that the fisherman, to steady the fish for the photographer, should, of all parts, have laid hold of the point of the tail, thus obscuring it. However, there is here a rounded point or lobe or "spade" projecting beyond the general rounded contour of the tail-fin. Faintly to be seen are spots on the dorsal fin and on the body—especially on the venter. Beyond the fact that this fish was taken at Palm Beach in 1918 there are unfortunately no data whatever.

At Daytona Beach: In April, 1931, a giant pointed-tail was taken near Daytona Beach. It had been left by the ebbing tide in a "low water slough" 5 or 6 feet deep, where it could thresh around but could not get away. In this it was captured by the fishermen. Entangled in their seine it was dragged ashore and with much effort was transported to a pier where it was put on exhibition. This pointed-tail, one of the largest

[2] Dr. C. H. Townsend in the *Bulletin of the New York Zoological Society* for November.



After Townsend, 1918

FIG. 3. A ROUND-TAILED SUNFISH TAKEN AT PALM BEACH

Note the round point of the tail held by the man's hand and the faint spots on the body.

Photograph by S. R. MacDonald, 1935

FIG. 4. ANOTHER PARTIALLY DRIED TAIL OF AN OCEAN SUNFISH

Compare this (Miami No. I) with that in Fig. 9 (from Daytona Beach).

specimens on record, was 8 feet 4 inches in "over all" length (of which the caudal fin measured 2 feet 2 inches), and the total depth of this fish (nearly round in outline) over the dorsal and anal fins was 8 feet 9 inches.[3]

The weight of this giant was estimated as at least 1,200 lbs. Great difficulty was had in handling it, and unfortunately no derrick was at hand for swinging the fish up for photography. This is a great misfortune to ichthyology, since this fish is not only one of the largest on record but also is the most beautifully spotted and colored of any specimen known to us. However, it is fortunate that MacDonald was at hand with a camera, and that he made every effort to get photographs showing as much of the body as possible. Fig. 5 is a head-on view of the fish, lying on the floor, showing the great size and the stretch of the dorsal and anal fins. Behind is the great spade-shaped caudal lobe, the point of which, however, does not show.

A better idea of the size of this giant may be had from Fig. 6. Here note the huge anal fin and the enormous tail—the great caudal lobe being unfortunately not shown in the photograph. The tail is separated from the body by a band, and everywhere are the spots so characteristic of the species. The tip of the caudal lobe had apparently been broken and had then healed. This mutilation (shown clearly in Fig. 8) could only have been effected by a shark or a barracuda (a fish even more dangerous than a shark). And just here it may be remarked that the figures of the pointed part of the tail of nearly every known specimen of this species show more or less mutilation of this part.

A photograph of the dried tail taken a year later is shown in Fig. 9. Here the hooked form of the central part is well portrayed, as are the fin-rays of the whole caudal fin and particularly the 5 in the lobe. Their absence from the center of the "point" is significant. There is reason to believe that here the rays are quite slender, and that in this dried tail they have gone to pieces and have fallen off. Unlike what is found in other specimens of the pointed-tailed sunfish, the hook here points downward.

The shape and the internal make-up of the tail are matters of prime importance in studying *Masturus*. Since these structures are wonderfully well shown in the tails of Florida specimens, we call particular attention to them.

[3] Record was made of this huge fish in *Copeia* by Hubbs and Giovanoli in 1931.

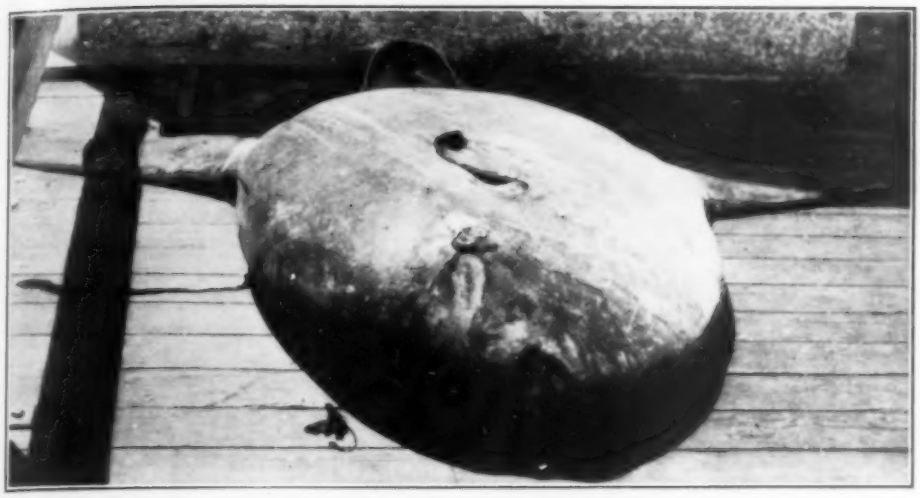
UNDESCRIBED POINTED-TAILS FROM THE EAST COAST

We have now come to that part of our article in which we will first describe some specimens taken long ago in northern Florida, wrongly named and never put on record. Then we will describe and figure four fine fish taken in southern Florida in the late winter of 1935.

Specimens at St. Augustine

At the "Alligator Farm and Museum of Marine Curiosities" on Anastasia Island at Saint Augustine are two mounted ocean sunfish labelled *Orthagoriscus mola*. However, these are pointed-tailed sunfish which will now be put on record.

The larger and older of these two fish (Fish No. I) was stranded on St. Augustine Beach in 1912. It is reported to have been 10 feet long and 11 feet 3 inches deep over dorsal and anal fins. Its weight was estimated at 1,700 lbs. Even now, after 24 years of drying and shrinking, it measures 8 feet long and 9 feet 7 inches deep. A photograph shows the remains to be in bad shape, the fins being dried and fragmented. A great enlargement from this negative shows the battered tail fin to have the unmistakable internal structure of that of the pointed-tailed sunfish. The lobe is badly torn, but in the enlargement it is seen to be composed of 4 or 5 rays, like those



Photograph by S. R. MacDonald, 1931

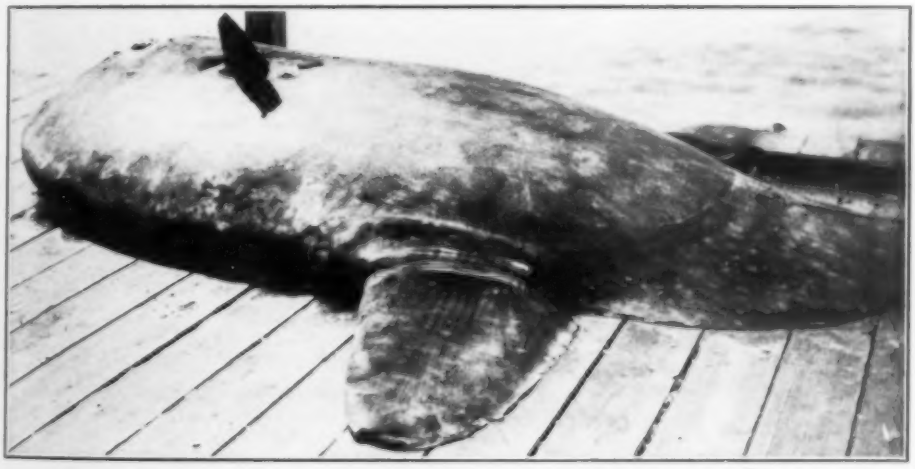
FIG. 5. THE DAYTONA BEACH OCEAN SUNFISH, 1931

HEAD-ON VIEW (FROM SOMEWHAT ABOVE) OF THE FISH LYING ON THE DOCK. NOTE THE SPADE-LIKE TAIL (POINT INVISIBLE).

shown in Fig. 9. Thus the internal evidence (internal in the literal sense) makes us sure that this is our ocean sunfish—the largest that has ever been recorded. With so many fine photographs of other pointed-tails at hand, it would be an anticlimax to reproduce the photograph of this battered fish. The structure of the caudal is so fragmentary that not even a line drawing can be made.

One of the owners of this museum[4]

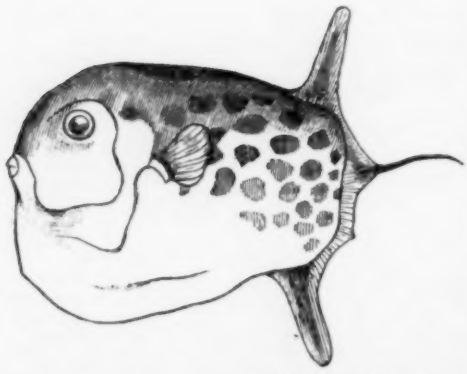
[4] Mr. George Reddington, formerly connected with Ward's Natural Science Establishment at Rochester, N. Y.



Photograph by S. R. MacDonald, 1931

FIG. 6. QUARTERING VIEW FROM BELOW OF THE DAYTONA GIANT

NOTE THE HUGE ANAL AND CAUDAL FINS (THE TIP OF THE LATTER UNFORTUNATELY NOT SHOWN).



After Perugia, 1889

FIG. 7. A YOUNG POINTED-TAILED *MASTURUS LANCEOLATUS*

NOTE THE WHIPLASH TO THE TAILFIN AND THE SPOTS ON THE UPPER AND HINDER PARTS OF THE BODY.

Photograph by courtesy of Leonard Giovanoli, 1931

FIG. 8. TIP OF TAIL OF DAYTONA FISH

NOTE THE DOWNWARD SWING OF THE MUTILATED LOBE.

writes that his recollection of the tail of this huge specimen is still fairly clear, and particularly since the fish was photographed and hundreds of post cards sold. He sends a pencil sketch and states that in the fresh fish the point of the tail extended 12 or 14 inches beyond the general contour of the caudal fin, and that the essential tail structure was identical with that of his other fish (Fig. 14). Since this is the largest pointed-tail ever taken, a figure of this giant is a great desideratum, and every effort has been made to find either a copy of the photograph or of the post card—but in vain.

The other sunfish (Specimen No. II) in this same private museum came ashore on St. Augustine Beach in 1929. Its total length is about 6 feet, and its depth over unpaired fins is 7 feet 8 inches. It has 18 tail-fin rays, about 7 of these in the "spade." The fish is so hung that the photograph made of it is not good enough to reproduce. But from it, however, a tracing has been made of the dorsal-caudal-anal region. This is reproduced as Fig. 14. Here may be noted the extremely long (and narrow) dorsal and anal fins, making the depth of the fish greater than the length. The whole caudal is unusually wide, recalling that of the Daytona specimen (Fig. 6). Especially noticeable is the long narrow pointed lobe placed above the general level of the body and cocked upward. This is in part due to shrinkage consequent on drying. Let the reader compare this with the tail of the Daytona Beach specimen portrayed in Fig. 9.

Masturus AT MIAMI

The months of January, February and March, 1935, were remarkable for the capture of four fine specimens of the pointed-tailed sunfish in this region, and for reports of twice as many more seen but not captured. The junior author was fortunately on the ground with

camera and notebook to record this remarkable abundance. These fish will be reported on by number in the order of capture.

For the first pointed-tailed sunfish (Fish No. I) MacDonald wrote under date of January 14:

Verily the Lord loveth us. During the early afternoon of January 11, while driving up the ocean boulevard about 15 miles north of Miami, suddenly, right before my astonished eyes, hanging on a post, I saw a *Masturus lanceolatus*. Think of it, there right out of a clear sky with no effort on my part was this much-desired pointed-tailed sunfish waiting to be photographed. This was done at once, as you may see from the enclosed print [Fig. 10]. I also made measurements as follows: total length 3 ft. 11 in.; height over dorsal and anal fins 3 ft. 11.5 in.; estimated weight 100 lbs.

Here is the story of its capture as given me by the owner of the fish. On January 9, he and two other men were out in a small fishing boat in the edge of the Gulf Stream about 4 miles from land and some 16 or 18 miles north of Miami. The fish when first sighted was swimming upright with its dorsal fin out of water. The power was shut off and the boat allowed to drift. The fish, seemingly curious, circled the boat several times and finally came close enough to be reached with a boat-hook used as a gaff and was hauled aboard. As it came over the side, a sucking-fish about 9 inches long dropped out of one gill opening. The fish was then brought ashore and hung up by a rope run through the body near the tail as shown in the picture.

In their first attempt to hang the fish, the men perforated the tail too near the edge and tore out a piece of the fin. This maltreatment shows clearly in all the photographs [*i.e.*, in Fig. 10]. The wrinkled condition of the skin is due to the suspension and to drying.

Photograph by S. R. MacDonald, 1932

FIG. 9. DRIED TAIL OF THE DAYTONA POINTED-TAILED SUNFISH

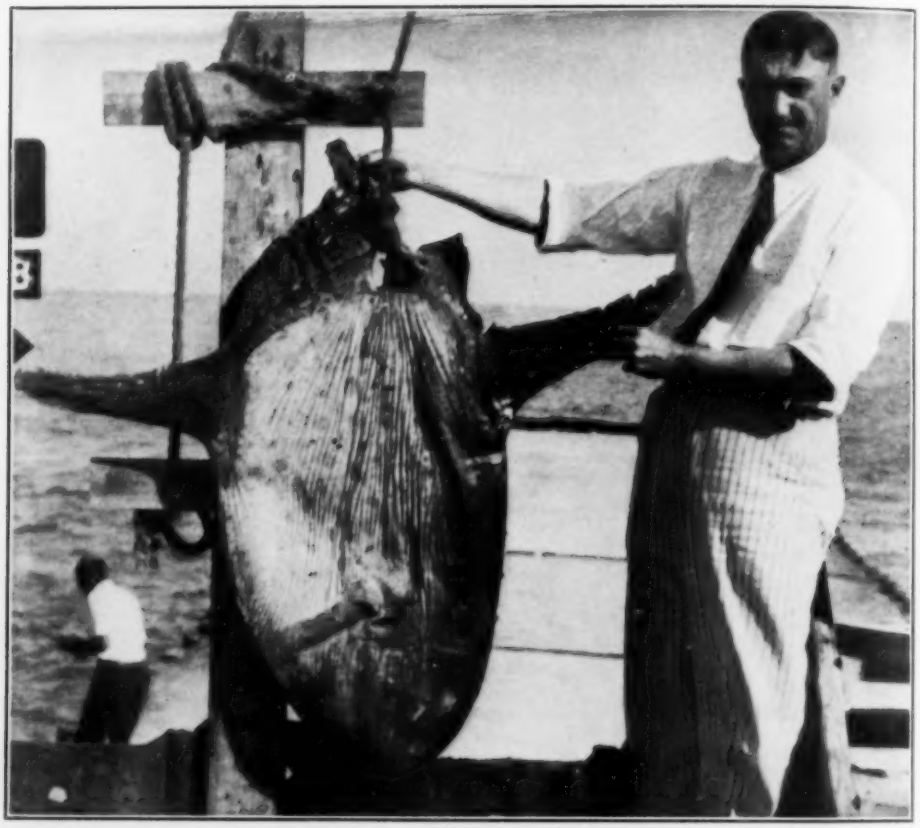
THE DRYING OF THIS TAIL HAS BROUGHT OUT THE FIN RAYS, SOME OF WHICH IN THE CENTER ARE MISSING. COMPARE THIS FIGURE WITH NO. 8

This photograph shows the features described in the preceding paragraphs. The upper part of the caudal fin has suffered much mutilation, but the "spade" or "thumb" is held by the junior author's hand just to the left of the suspending rope. Note the spots on the white part of the body. Some can be

seen on the dorsal and anal fins. The tail fin is divided into two parts—a thick inner part and a thinner outer. The whole tail fin is so thickly covered with large irregular spots that these sometimes become confluent and make blotchings.

of the tail shown in Fig. 4. Here may be made out 6 thread-like rays, essentially similar to those seen in Fig. 9. No other figures of the tail showing these structures have ever been published.[5]

On January 19, MacDonald wrote:



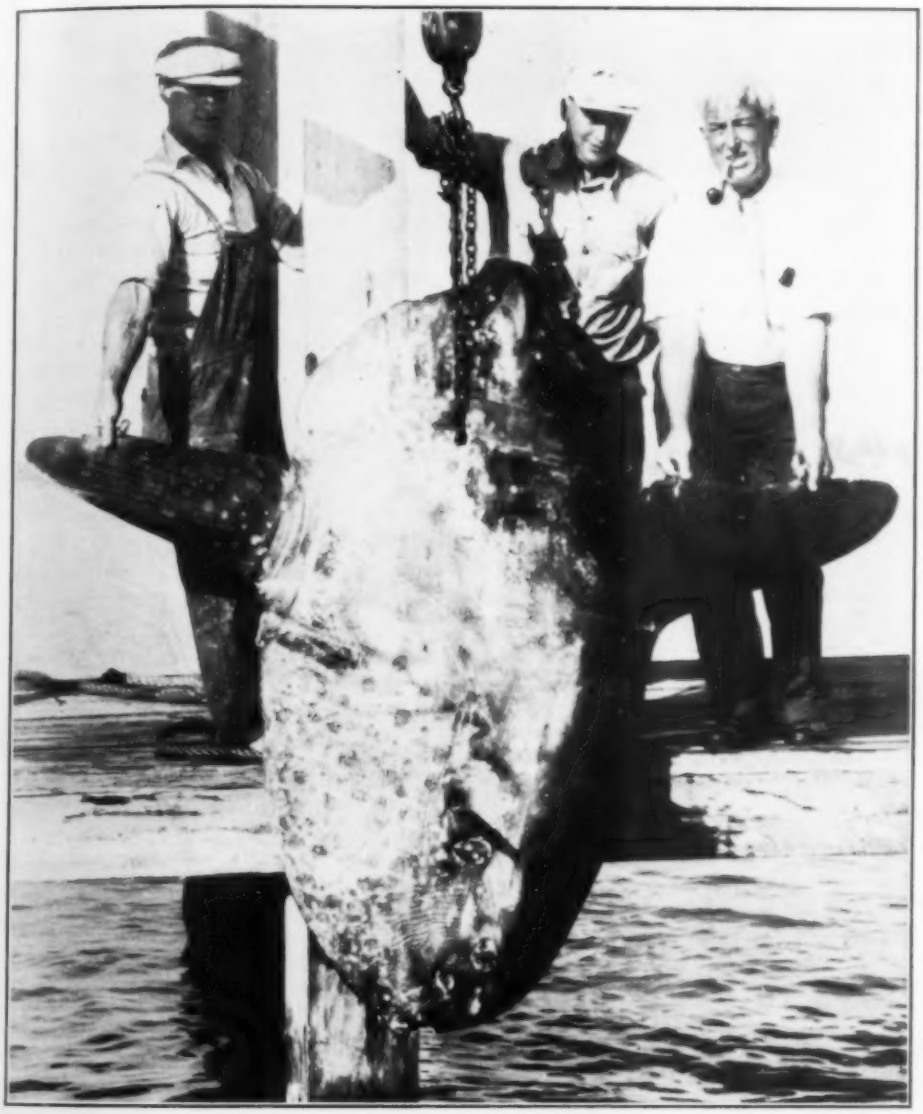
Photograph by Mrs. S. R. MacDonald, 1935

FIG. 10. THE FIRST MIAMI *MASTURUS* AND THE JUNIOR AUTHOR
THE TAIL HAS BEEN BADLY MUTILATED IN THE EFFORT TO SUSPEND THE FISH.

Since our chief interest in this fish is concentrated on the anomalous tail structure, a photograph was made of its tail after drying had been going on for several days. This photograph (*mirabile dictu*) shows faintly but definitely certain internal structures. Since the reader's attention has previously been called to these, it is again directed to the point

"This locality seems to be *Masturus* Highway. A second fish, and a big fellow, was captured yesterday—6 ft. 4 in. long and 8 ft. 3 in. deep, estimated weight 500 lbs." A photograph of this fine fish is shown in Fig. 11.

[5] The fish later came into possession of Mr. Albert Pflueger, naturalist and taxidermist of Miami, who plans to mount the skin and display it in his private museum.



Photograph by courtesy of Major F. P. Bradford, 1935

FIG. 11. PORTRAIT OF MIAMI OCEAN SUNFISH NO. II

NOTE THE STUBBY TAIL AND THE SPOTS ALL OVER THE BODY. THE HEIGHT OF THE MEN GIVES A "YARDSTICK" FOR ESTIMATING THE SIZE OF THE FISH.

This second sunfish (Fish No. II) was taken in the northern end of Biscayne Bay close to the outlet to the ocean known as "Baker's Haulover," about 5 miles north of Miami. It was seen floundering about in shallow water, and two men went out in a skiff, shot it and then brought it in and swung it up by a derrick, as the figure shows. The tip of the tail is short and rounded and has evidently been mutilated. It is even shorter than the tail of the Palm Beach fish (Fig. 3). Such abbreviation is common in the tails of most specimens of the pointed-tailed sunfish figured and described.

The third pointed-tail (Fish No. III) was captured on January 28 on the inside edge of the Gulf Stream, a little south of the mouth of Miami Harbor. It was seen swimming slowly about with its dorsal fin out of water, and was so unafraid that it allowed a large fishing boat (110 feet long) to approach it near enough for four men to secure it with long-handled gaffs. The captain of the boat reported that its sides were iridescent, with blue spots showing distinctly. These have faded, as Fig. 12 shows. The total length of the fish was about 7 feet, the "over all" depth was but 2 inches more and hence this millstone fish was almost round in outline. In the figure the dorsal and anal fins are curled backward, so one can not estimate the true depth. Its weight was variously estimated at from 700 to 1,000 pounds.

When brought ashore, the specimen was not swung up high enough for the tail to clear the ground (Fig. 12). However, the three unpaired fins were cut off and sent to the American Museum—a wholly unique gift, since there are literally no others in any museum.[6] These fins came in perfect condition, and the tail fin was photographed, as may be seen in Fig. 13, the only photograph showing the fresh fin known to us. The general shape of this fin is accurately shown. Above

[6] For these fins and for photographs of this and other Miami specimens, the American Museum is greatly indebted to Mr. Pflueger.

Photograph by S. R. MacDonald, 1935

FIG. 12. OCEAN SUNFISH NO. III, MIAMI, 1935

THIS IS THE LARGEST SUNFISH (ABOUT 7 FEET IN BOTH HEIGHT AND DEPTH). THE POINT OF THE CAUDAL IS NOT CLEAR OF THE SAND.

Photograph by H. S. Rice

FIG. 13. THE WHOLE TAIL INCLUDING THE "SPADE" OF FISH NO. III

NOTE THE UPTURNED CAUDAL LOBE. THIS FIGURE OF THE TAIL FIN IS UNIQUE—THE FIRST ONE EVER PUBLISHED.

Sketch from a photograph by S. R. MacDonald, 1935

FIG. 14. OUTLINE SKETCH OF TAIL OF ST. AUGUSTINE FISH NO. II

NOTE THE SLENDER DORSAL AND ANAL FINS, AND THE WIDE CAUDAL FIN WITH ITS TILTED LOBE.

Sketch from a photograph by courtesy of Albert Pflueger, 1935

FIG. 15. OUTLINE SKETCH OF MIAMI *MASTURUS* NO. IV

THIS FISH HAS A LARGE TAIL FIN, THE LOBE BEING ABOVE THE MEAN LEVEL OF THE BODY AND TILTED UPWARD.

the median level is the spade-like lobe which points somewhat upward. Later this tail will be dissected for the muscles and then deeper for the fin rays. It is expected that these dissections will help reveal some of the relationships of this interesting sunfish.

Just here fate overtook us—the junior author was laid low with the influenza for about 30 days. But even from his sick-bed he wrote that the captain of the boat which captured our third fish reported that on February 11 he saw a school of 8 pointed-tailed sunfish disporting themselves in the Gulf Stream. This man certainly knows our fish, and his testimony indicates its presence and abundance off Miami.

Another fine specimen (Fish No. IV) was harpooned on March 9 in the ship's channel at the south end of Miami Beach, connecting Biscayne Bay with the ocean. When sighted it was swimming upright in the water, not on its side. Two sucking-fish were found in its gills. These fish are constant companions of the ocean sunfishes, and it is commonly alleged that they are of one specific kind—*i.e.*, that the sunfish acts as host to only one particular species of sucking-fish. This is a very interesting matter but one which can only be settled by examining a large number of such "suckers" which are definitely known to have been obtained from particular ocean sunfishes.

We had bad fortune with this specimen. MacDonald was at San Marco on the west coast of Florida and missed it entirely. Gudger was spending a short vacation at Sanibel Island higher up on the west coast. Pflueger telegraphed Gudger on Sunday, March 10, but it was impossible for him to go to Miami that day. And finally on the late afternoon of March 10, the fish had become so offensive that it was necessary to heave it overboard.

The photograph of this specimen was not taken until the great fish had lain long on the dock and had got in bad condition, hence it is not suitable for reproduction. However, it is valuable to show the proportions and the form and the set of the fins, and from it has been made the outline drawing shown in Fig. 15. This shows that the caudal lobe arises above the median level of the body and points slightly upward. The extreme end has surely undergone abbreviation. This caudal lobe markedly resembles that of the second Miami fish (Fig. 11). Unfortunately, no measurements of this fish were made, but judging by the men beside it in the photograph, it must have been between 7 and 8 feet high and perhaps a foot less in length. Its estimated weight was put at about 600 pounds, and this is presumably not an exaggeration.

Comment should be made here that all these pointed-tailed sunfish at Miami swam slowly about with part of the dorsal out of water. They are poor swimmers, are sluggish and inert. They seem unafraid of men and boats, have little hesitancy in approaching them, and when a fish is gaffed, harpooned or lassoed it makes no resistance other than an effort to get away. Practically nothing is known of its life history, save that its very young are totally unlike the older young—*i.e.*, they undergo a distinct metamorphosis. The senior author is making a special study of the structure and development of the tail in both very young and in adults. When published it is hoped that this study will throw much light on this extraordinary organ.

HOW THE POINTED-TAILED SUNFISH HAS REACHED THE COASTS OF FLORIDA

This question has long ago been asked by the reader, and we will now endeavor to explain the occurrence of the fish in such numbers in Florida waters. But first it must be noted that for the other side of the Straits of Florida, Luis Howell Rivero[7] has recorded the capture of a fine specimen near Havana. Further, he has kindly let us see an article now in press describing five other fishes of this genus taken near Havana. The occurrence of these six northern Cuban specimens ties up absolutely with our eight records set out above. All might be called "Straits of Florida specimens," and the occurrence of all fourteen fish can be accounted for by one explanation.

Johannes Schmidt, the Danish oceanographer, by the capture of a large number of larval and post-larval *Masturus* in the Sargasso Sea, has shown it to be a breeding place for this fish. Many young specimens of different ages have been reported from this great "dead water" of the north Atlantic. Adults in the southern parts of this sea might stray into the North Equatorial Current of the Atlantic, and be carried by it between the various islands of the West Indies, into and through the Caribbean-Gulf waters, and out via the Gulf Stream between Cuba and the Florida Keys. Thus the four little ones taken off Pensacola came to that region and thus Rivero's six adults were brought to the Havana coast of Cuba. Thus also the four Miami fish, the small Palm Beach specimen, the Daytona giant and the two St. Augustine specimens, were distributed along the east coast of the peninsular state.

That numbers of pointed-tailed ocean sunfishes have been taken along this very coast and mistakenly identified as the round-tailed form, *Mola mola*, can be little doubted. And now that the pointed-tailed sunfish is being recognized as such when and where captured, it may be confidently expected that other specimens, and possibly in fair numbers, will be reported from the east coast of Florida.

[7] *Memorias de la Sociedad Cubana de Historia Natural* for 1934.

THE HEREDITY OF THE MODERN BED—AND ITS INBORN WEAKNESSES

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How and why things start is often lost in obscurity, yet it is origins which explain many puzzling things. I have buttons on my coat sleeves because sleeves used to unbutton to make it easy for swordsmen to roll up their sleeves. The back of my coat is split because years ago a split coat was helpful when transportation was chiefly on horseback. On every hand we can find such illustrations of vestiges we have inherited from previous generations, vestigial characters which were once useful, but which no longer appear to serve a purpose. We are heirs of the past, and its obedient slaves.

The quest of origins, the attempt to find out how and why things started, is unexpectedly practical. It is always a fascinating venture. Mankind's curiosity about how things started and how they changed through the course of history seems never to be satiated. Perhaps it is never fully satisfied because of the gaps in written history and the long puzzlings necessary to unravel the still older unwritten history that is revealed in the mounds, village ruins, burial places and fossil remnants of more ancient ways of living.

The gaps in the story of men's resting places are mostly prior to the Bronze and Iron Ages. Archeologists and antiquarians have given us a fairly complete story of mankind's sleeping practices for the last 20,000 years.

Earlier than that there is no significant record, and probably for the obvious reason that man had not yet invented the bed. These remote ancestors of ours had invented fire, and were weaving clothing for themselves before they discovered the helpfulness of a bed in their daily rest and recuperation.

Around a million and a half years ago pro-human families lived in the plains of central Asia. Their beds were nests in trees. The important thing in their existence was safety from prowling night animals that threatened their security of life. So they slept in trees.

The next advance in habitations, and we can not quite call them human habitations yet, was to take refuge at night in natural shelters. Years later our pro-human ancestors discovered they could make their own protections out of stones. These earliest houses—if we may call them houses—were in fact hiding places in which one could sleep in relative safety.

Our very word bed is derived from an Indo-European word root meaning "a dug-out place for safe resting." And to-day, a million and a half years since our forerunners built simple stone defenses for their sleeping places, we nevertheless find some human hesitancy to sleep in an upper berth or in the top of a double-decked bed, for fear of falling out.

It may be the expression of a remote ancestral trait which prompts most of us to lock our bedroom doors and not to open the windows too wide—while a few of us so prize a safe place for resting that each night there has to be an inspection to make certain no one is under the bed.

Perhaps the biggest achievement of all time was early man's invention of fire. This changed the type of food he consumed. It made it possible for him to start migrations and to live in regions

which would have been hostile without the blessing of fire. As he moved from the temperate and uniformly mild regions which cradled the race he felt the need for clothing. Fortunately the frontal lobes of his brain had developed sufficiently so that he was capable, not only of throwing animal skins over his shoulders, but could invent—as he did—looms on which to weave textiles. Needles were used by men and women of the late Stone Age, less than 30,000 years ago. And they were weaving cloths on looms some 20,000 years ago. Some of these looms which are now in museums can be used for weaving at the present day.

All these interesting developments by our remarkable ancestors made it inevitable that sooner or later they would make use of beds. But there is one thing we must mention, because it was of cardinal significance in leading these primitive people to want to have something special on which to sleep.

Pro-human men had a stooped posture. It was natural for them to sleep or rest in a semi-curled position, and the nest in the crotch of a tree conformed to his natural posture. That was around a million years ago.

The visual lobes at the back of his brain developed, and early man started to make increasing use of his sense of vision. He began to stand erect in order to peer into the distance to locate enemies or food. By the time he had invented the needle and loom he was of fairly erect stature and found it somewhat uncomfortable to curl up in his sleep. He could curl up, but he doubtless found that when he did he awoke with muscles stiff and joints sore from the stretching into unnatural positions. He was developing to walk erect, and to sleep straight he needed a bed of some sort. A hammock, with its gracefully curved position, would have been tailor-made for the sleep of his pro-human ancestor, but not for our man of the late Stone Age.

So some 20,000 or so years ago this Neolithic man provided a place for sleeping in his huts. Elevations at one end of the single room which constituted his home were used for sleeping. Furs and coarse textiles were used for coverings; the mattress was crumpled grasses or leaves; the springs were the hard ground. All in all, this was doubtless comfortable so far as warmth was concerned, but I feel safe in imagining he often wished for a hollowed-out spot in which he could place the downward arm.

This first sleeping chamber of the race made it possible for Neolithic man to sleep with his spine in more or less of a straight line. His changed habit of life, with its erect walking, made this more or less of a necessity, and his new-found way of sleeping straight undoubtedly helped him to walk straight and erect.

I presume none of us would wish to exchange sleeping places with this long removed relative of ours. But I wonder if perhaps he was not pretty well off at that? To be sure, the solid earth of the sleeping elevation of his hut was hard and unyielding, and the little space was so narrow that he very probably rolled out of bed many times; but despite these foreboding aspects, I think this old Neolithic man, with his growing craftiness and culture, had good sleep. His life was simple, of course, and he had very few worries to keep him from sleeping.

And, above all else, he had the splendid sleeping habit of spending more time on his rough and uncomfortable bed than most of his nieces and nephews do today. All during the darkness he slept, and if he did not sleep he was at least quiet and resting from twilight until sunrise. He had regular hours of retiring and the desirable habit of long hours of sleep or rest.

Then his invention of fire began to cut his sleep short. It was so enjoyable to sit in the carefully nourished glow of the fire and chat, keeping one eye on the precious fire lest it die out, while the

Courtesy, Museum of Fine Arts, Boston

A BED OF THREE THOUSAND YEARS AGO.

THE SLOPING, HARD-BOTTOMED BED WITH AN EQUALLY FIRM NECK REST TO PROTECT THE COIFFURE, USED BY QUEEN HETEP-HERES I, MOTHER OF KING CHEOPS OF THE FOURTH DYNASTY. THIS IS A REPRODUCTION OF THE ORIGINAL REMOVED FROM THE TOMB; THE ORIGINAL BED IS IN CAIRO.

other eye was kept on the fringe of darkness watching for pairs of spots with a greenish glow which would reveal the presence of some prowling enemy.

Mankind no sooner began to make significant inventions than, lo and behold! these began to work against him as well as for him. And civilization ever since has been largely a compromise between the pros and cons, the virtues and the evils, of inventions.

First it was his precious fire that began to undermine man's hitherto good sleep habits. A few thousand years later tallow candles and whale-oil lamps made it still more pleasant to stay up. Then kerosene displaced the candle in adding to the cheerful brightness of the night, only to be displaced in turn by electricity, which can turn night into day and which has turned the sleeping habits of thousands of persons topsy-turvy.

But that is getting a little ahead of our story. When mankind began to cut short its rations of sleep, it began to discover how uncomfortable the sleeping elevations were. And they quite naturally noticed that they got more tired during the day. So what is more logical than, as the late Dr. Walter Hough, of the Smithsonian Institution, discovered, for women of the Stone Age to invent chairs after their mates had previously built beds of a sort.

The bed antedates the chair by many centuries, but the first chairs were more like the chairs of to-day than the beds were like the beds of to-day. As soon as primitive man started to civilize himself he robbed his night sleep and took to inventing beds so he would sleep better, and chairs so he could rest more during the day. He must have been altogether human!

The earliest written record of beds is probably that found in the Book of Esther. Coarse stuffed pillows or cushions were piled in a corner of the room to be used as beds at night and as seats in the daytime.

In the Bronze Age, which reached its zenith in Egypt, we discover that inven-

tiveness had hit upon the idea of making these sleeping elevations movable, like a chair, so they could be put at any place in the house—this may mark the beginning of the practice of rearranging the furniture every few months.

But the Egyptians were as artistic as they were ingenious. Exquisitely fashioned from rare woods, ivory, bronze, copper—even of gold and silver—their beds became objects to gaze upon and admire so that their resting qualities became almost secondary. Solomon's bed was made of cedar of Lebanon.

A strange thing about these Egyptian beds is that they are practically all single beds, and narrower than our single beds of the present day. There were a few wider beds, and also a few which were so tall that a ladder or special steps were needed to climb up to them.

The typical Egyptian bed was a narrow affair, half bed and half couch, which was used as much for daytime lounging in their languorous climate as it was used for night-time sleep. There are records, also, of what we might call sleeping porches in Egypt. Cleopatra had one. Her bedroom lacked nothing in art and luxury. Her bed was made of ivory and gold, and was of an immense size. It was covered with silken throws, embroidered with gold cord. A gold god of love, a yard tall, stood on the footboard and aimed a golden arrow at his sleeping mistress. On the piazza just outside her bedchamber there was an equally luxurious outside bedroom. This forerunner of our sleeping porch contained a bed made of marble and gold. Here the Serpent of the Nile rested on hot nights.

That was how royalty slept in the late Egyptian civilization. Narrow beds were being abandoned, and a curious development had started which persists in vestigial form to-day, like the dueling buttons fashion still keeps on men's coat sleeves.

Outdoor sleeping had its advantages in those ancient days on the Nile, and it had a number of disadvantages, just as it still does to-day. To protect the sleeper from the burning sun and the inclemencies of weather, a canopy overhung the bed. The corners of the bed were extended up into the air and a canopy of silk or linen was suspended between these corner posts. That was the highly practical beginning of the four-poster bed so cherished in to-day's tradition. A netted tent of linen gauze also enclosed Cleopatra's bed to provide protection against insect pests.

The origin of the canopy, or tester, was thus plainly a practical necessity. Long after the necessity had ceased to exist, the canopy and overhanging drapes were retained and developed, especially by the French courts, into highly decorative appendices of no practical use whatever.

The first bed springs, if we may call them such, were devised by the Greeks. Most of their beds were narrow, serving as a lounging couch by day, but they discovered there was more comfort if the top of the bed was made of bands of stout leather, laced between two heavy boards at the sides of the bed. When covered with skins this was much more comfortable than skins placed on top of a marble or bronze slab. That simple bedspring of leather thongs remained the only spring foundation until such a recent date that many persons remember the change. But that is getting a bit ahead of our story.

In the later Greek civilization considerable luxury was developed around their sleeping paraphernalia. Pillows, especially, were developed; Corinth and Carthage became famous as places which, among other things, made wonderfully comfortable pillows. Small apartments must have developed also, for their vase paintings record folding beds.

The early Romans slept on mattresses stuffed with reeds, hay, wool or feathers. The cotton mattresses which the Egyptians had developed were too difficult for the Romans to obtain. The Roman beds

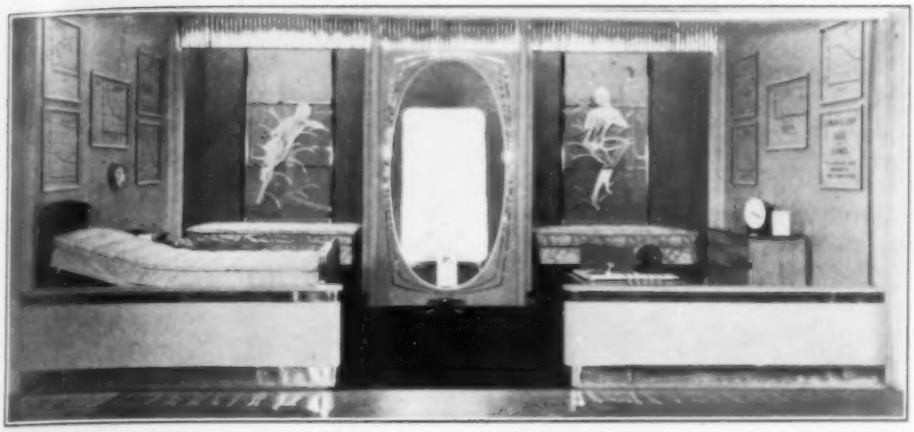


EXHIBIT OF SLEEPING EQUIPMENT AND THE METHODS OF STUDYING SLEEP
PREPARED BY THE AUTHOR FOR THE CENTURY OF PROGRESS EXPOSITION.

were usually narrow ones, and of considerable height from the floor—the height from the floor showing the Egyptian influence.

The height—so great as almost to make a person nervous—was a precaution which was started to keep rodents and snakes from getting into bed. Just as in the northern European countries, at about the time the Roman civilization was at its zenith, heavy railings were built around the bed, and the home—whether hovel or palace—was overrun with large dogs of the Great Dane and mastiff strains as a protection against wolves. Practically everything about a bed frame which we have to-day had some useful purpose of this sort at the inception, although it may be purely decorative to-day. It is little short of amazing how through hundreds of centuries the original meaning of a bed as a safe place for resting is clearly shown in the architectural features of the bedsteads which were shortly to become elaborate and enormous things.

There was a break in progress after the fall of the second Roman Empire. Practically every civilized accoutrement disappeared in the wanton confusion of the early Dark Ages—although in the northern portions of Europe the Vikings were calmly using wooden bedframes filled with generous feather mattresses from about the eighth to the eleventh centuries. The rest of Europe, however, was sleeping on the hard ground. Everything was chaotic, and living reverted to the most primitive terms.

A bench, a chest, a few skins and, with a favored few, some pieces of linen, constituted their complete living equipment. The chest was a veritable Pandora's box. In it were stored almost all their worldly possessions. In the daytime it was used as a table. At night a few skins were spread over it, and, presto changeo! it became their bed. Those not fortunate enough to have prior rights to sleep in the elevated security of the chest top, had to content themselves with wrapping in skins on the floor. When linens were available, the average person undressed for sleep, wrapping his naked body, mummy-like, with large linen cloths, perhaps to keep the furs from tickling.

Then civilization slowly reestablished itself, human life and property became more secure, and people stopped their wandering existence. In the thirteenth century all luxuries increased. The Pandora's box grew, and as it enlarged it changed its form into the crude bedstock.

The first bedstocks were movable struc-

tures, since the possibility of forced moving and wandering with all one's possessions was still in the backs of people's minds.

With the growth in political stability, however, the bedstock became an integral part of the house. It was built into one corner of the room as a permanent part of the walls themselves. Perhaps some traveler brought back accounts of such beds, or in some monastery a studious monk had translated records which told about the bed niches in ancient Pompeii.

THE LINK SPRING DEVELOPS A PERMANENT SAG.

THIS IS HOW EVEN A BRAND-NEW ONE SAGS WHEN IT IS SLEPT IN.

At any rate, the influence of older civilization was manifest, the bedstocks became highly ornamented, and the old canopies and protective curtains were gradually revived as they could be afforded.

Not yet did homes have bedrooms. The ideal purposes of a separate room for sleeping was achieved indirectly, through the growth of decoration. From the built-in bed, resembling our modern railroad or steamship berth, the separate bedroom developed through the decorative impulses. Carved panels were added to the bed niche, it was built out farther into the room, heavy draperies were later added to curtain it off, in Scotland, Brittany; in Holland folding wooden shutters were used in place of draperies, and these folding shutters can be seen to this day in many of these old sleeping places. But the bed had become so bulky and formidable an object by this time that it occupied most of the room. There was not space for other furniture, and without realizing it people had developed bedrooms.

The elaborate carvings in northern Europe, and the paint and gilt decorations in southern Europe had not been born to die unseen, however. For centuries the bed remained the prized piece of furniture, not so much for qualities promoting rest as it was a possession of luxury to be displayed in all its beauty to make one's friends envious.

Louis XIV had 413 beds, many of them enriched by embroideries in pearls on a background of silver or gold. The carvings were by Proux or Caffieri, while the gilding was by La Baronniere.

The nobility received distinguished visitors in their bedrooms, and in General Grant's day, modesty being more cherished, beds were made of elaborate walnut carvings with an upholstered seat built in at the foot of the bed, so visitors could be received in one's bedroom but without the embarrassment of the host being in bed. This suggests that the rumble seat started in the bedroom.

During the gorgeous monarchy in France there was no blushing about using a bed as a comfortable throne from which to converse with visitors. The term "bed of justice" developed from the custom started by Louis XI of having his own bed in parliament on which he reclined, while the princes were seated, the great officials standing and the lesser officials kneeling. Petitions were heard, ministers instructed and courtiers visited while the regent or host enjoyed the soft comfort of feather bed and silken pillows.

Hard-headed northern Europe, however, was meanwhile developing ideas to make the bed more restful. And to this

day in Scandinavian countries we can still see the sloping bed they developed. This bed was made at an incline, so that the sleeper's head was higher than the hips, and the hips higher than the feet. Sloping in some examples most precipitiously from head to foot, these beds became popular for the belief that they drained the phlegms from the body and promoted better sleep. The circulation of blood was, of course, not discovered at this time.

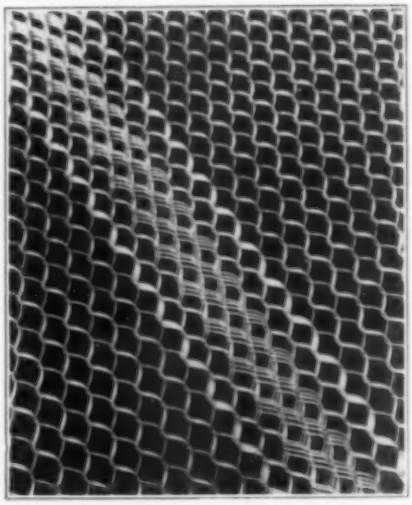
In the laboratory we have experimented with the quality of sleep while one is sitting up all night, and have found it is of a rather poor sort. We have not yet experimented on sloping or tilting beds, but it is undoubtedly worthy of study.

Louis XIV may have possessed 413 beds, but the English at about the same time had no need for such a large number. In an efficient fashion the English particularly developed a type of bed which certainly should have been safe resting places, so far as there is safety in numbers. Let us draw a background for appreciating this rather spectacular development.

We usually think of a Roman bed as a couchlike affair, of rather narrow proportions, which was used for eating as well as napping. This evolved into the Roman triclinium, or three-sided bed, which extended around the three edges of the table, leaving the fourth open for the slaves to serve the viands.

The English development some 1,500 years later was also a three-in-one bed, called Trinity. Of ample size, the high top layer of the bed provided a sleeping place for the immediate members of the family. To be pulled out at the side was another mattress, equally ample, which was used by the favored attendants or for the overflow from the family itself.

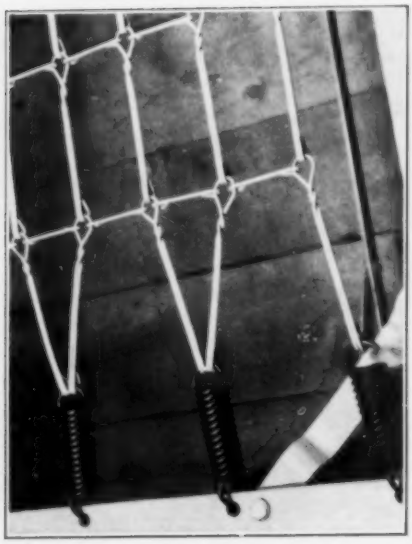
And at the foot of the bed a lower level was pulled out, still of ample size, which was used by the servants. Thus



A FABRIC TYPE OF SPRING.
THIS IS THE CHEAPEST—AT THE START. I PAID $3.00 FOR THIS SPRING.

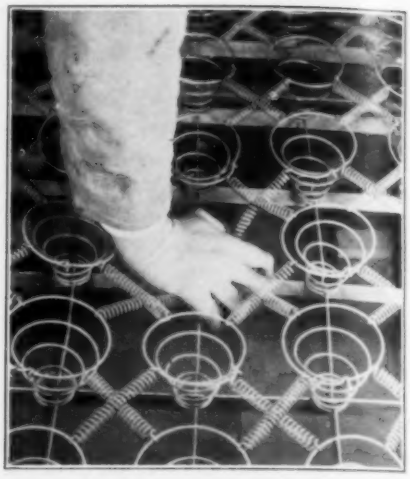
did the English go in for efficiency rather than for a great number of beds. In fact, they had few beds, typified by the condition in some of their castles, where out of 40 rooms only 8 were sleeping rooms. These old trinity beds still furnished adequate sleeping space, and when unexpected guests arrived there was always room to be found for them on one of the top levels of the bed.

THE FABRIC TYPE OF SPRING SAGS WHEN A PERSON IS ON IT, AND FINALLY DEVELOPS A PERMANENT HAMMOCK-LIKE SAG.



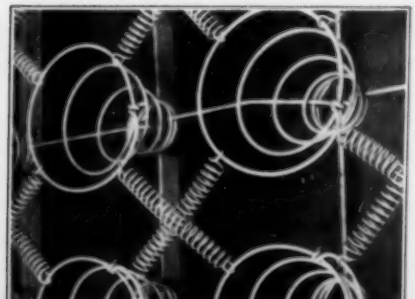
THE LINK TYPE OF SPRING.

THE HEAVY COIL SPRINGS HOLD THE LINKS OF WIRE TAUT. ON THESE, ONE MERELY SLEEPS ON TAUT WIRE.



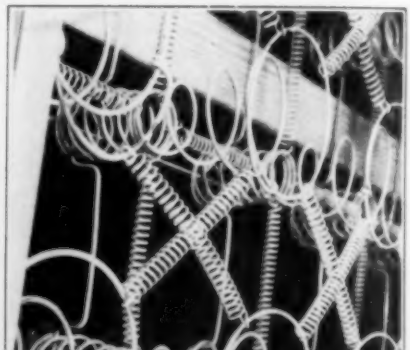
THE ACTION OF THE COIL SPRING

THE COIL SPRING, WHETHER SINGLE OF DOUBLE-DECKED, GIVES WHERE GIVE IS NEEDED, WITHOUT SAGGING. THE SHOULDERS AND HIPS, ON SUCH A SPRING, DO NOT CARRY MORE THAN THEIR JUST SHARE OF WEIGHT.



THE COIL TYPE OF SPRING,

MADE BY MANY MANUFACTURERS, IS THE BEST ALL-AROUND. THIS IS A CHEAP ONE; THE COILS ARE SHALLOW, BEING ABOUT FOUR INCHES DEEP.



A BETTER GRADE OF COIL SPRING.

THE COILS ARE ABOUT 8 INCHES DEEP, AND HELICAL IN CROSS-SECTION. TWICE AS MUCH SPRING IN THE SAME BED.

When the guests planned any lengthy stay, they usually brought along their own beds. This was common throughout Europe; the highways were filled with carts loaded with the beds of the travelers, reminding us of our own tourists a few years ago when tourist camps were at their height of popularity.

The old trinity bed, which is the obvious forerunner of our modern trundle bed and of the studio couch which can be expanded to make more sleeping space, reached its pinnacle in the famous Bed of Ware, which has been immortalized by Shakespeare and can now be seen, upon the payment of twopence, at Rye House, Roxbury.

Thirty years were spent by the cabinetmaker, Jonas Fosbrooke, in constructing this amazing bed. It was not the carving —of which there was much—that immortalized this bed. It was its size. The top of this bed could, and did, accommodate 68 sleepers. The trundle bed under it provided space for 34 others. A grand total of 102 could sleep in this wonderful bed of Ware, about which you can read in "Twelfth Night."

Rather too large for the modern-sized family, this bed so pleased Edward IV, to whom it was presented in 1463, that he promptly pensioned Jonas Fosbrooke for the rest of his life. And the royal chamberlain, of course, prepared a special list of rules of etiquette for the horde that could sleep in this marvel. I do not know whether this list contained instructions that all should turn over at the same time or not. And it is rather distressing to imagine how one restless sleeper would disturb the 101 otherwise sound sleepers. But it did afford the safety of numbers and leave the other rooms of the house for feasting and for the inevitable dogs.

It was obviously architecture rather than hygiene that developed beds up to the threshold of our times. Beauty of an heirloom rather than comfort seemed to be the motive. Display rather than relaxation, elaborate trappings rather than anything to give restful sleep.

The Greeks had used leather thongs, which had some resiliency and give, as a foundation for their mattresses. Mostly it was hard wood bottoms which were used, and on top of these sticks of straw, grasses, leaves or feathers were used—and these are probably still used more widely throughout the world to-day for mattresses than any other materials, except possibly cotton.

Although the resting qualities of beds apparently were not improved until very recent generations, men have tried ways of getting more rest out of equipment which really belongs to the ages. Charles Dickens, for example, always carried a small pocket compass with him when traveling, and would use this as a guide in having the bed placed so that his head pointed north as he slept. Some years before this time the Abbé d'Entragues slept with his arms tied above him.

At the time of Louis XVI an enterprising character, Cagliostro, had sold miraculous beds which he pretended would cure rheumatism; this amusing charlatan became so well known and his beds so popular among the credulous that Dumas used him as the central character in his delightful "Memoirs of a Physician."

And Merrie England—home of the famous and ample Bed of Ware—saw a revival of these supposedly healing beds in 1779 when impresario James Graham opened his Temple of Health in London and exploited his "celestial bed." The magic of Graham's cures and his celestial bed were claimed—by him—to assure one would live to be 100 years old. He must not have slept in his own bed, and not taken his own diet, for he died before he was fifty.

The Greeks, before the days of such fakirs as Cagliostro and Graham, had their sincerely operated Temples of

Sleep. To these Temples repaired those whose slumbers were disturbed, to be hypnotized by the priest and laid in a niche in a stuporous condition suggesting sleep.

But the black magic of mesmerized beds or hypnotized Greeks or even the scientific compass of Charles Dickens is a bit afield from our main story. It is to some epoch-making changes in the bed itself we must look for the changes which give our present-day—or rather present-night—comfort.

The leather-thong bed spring of the Greeks practically disappeared, but late in the Renaissance we discover that the hard board bed surfaces were being replaced by a network of ropes. These old rope beds, like the acrobat's safety net, had some stretch, but not as much rebound. After a few weeks they were stretched into a hammock-like sag.

It was a regular chore at house-cleaning time to enlist the services of a strong man to tighten up the slack. James Liddy did not relish this chore, any more than he enjoyed sleeping on a rope bed with a sag which folded him up like a half-closed jack-knife.

This James Liddy lived in a city which has peculiarly nurtured inventive minds. Dr. Guthrie had just invented the use of chloroform as an anesthetic only a few miles from Liddy's home at Watertown, N. Y., a city which was later to give the world the 5 & 10¢ store and shredded wheat. About 10 years before the civil war, Mr. Liddy, to whom each of us is immeasurably indebted, sat waiting for his wife. As he sat in the buggy he was struck with the superior comfort of the spring-upholstered cushions, and rousing himself slightly from his drowsiness the idea skyrocketed into his head: Why not use buggy springs in place of ropes to make beds comfortable?

In a spring wagon factory at Watertown he gathered together an assortment of old buggy springs and installed them in his four-poster bed to take the place of the annoying and sagging rope. That was the first bed-spring, a typical Yankee invention which was not patented and which quickly spread into thousands of homes. James Liddy should be among the immortals, but he remained a poor man all his life—a typical Yankee inventor.

After the buggy spring contrivances had been in use for a few years, Liddy worked out the idea of using spiral springs which every one has found to their lasting comfort is an improvement over methods of sleeping which for some 20,000 years had remained essentially unchanged until this inventive Yankee carpenter in northern New York state went to sleep in his buggy, all because his wife took an unusually long time on a shopping errand.

The spring is practically in universal use among civilized peoples at the present time. It has made more sleeping comfort than all other historical changes in beds and sleeping equipment. There is no magic to the bed-spring; all it does is to allow one to relax on a yielding surface, which supports the body uniformly and naturally in all positions and in all places. It gives a buoyant rather than a hard or misshapen surface to support the mattress which cushions our body.

Three general types of bed-spring have come into use since Mr. Liddy's original buggy spring. These differ as much in sleeping quality as they do in mechanical construction, and it is wise to be familiar with these three variants of the idea of buoying the body.

Each manufacturer as a rule makes all three types, to satisfy different markets, so in discussing the merits and demerits of the three types I am giving no testimonial for any manufacturer. What I am trying to do is to give the customer the help instead of the manufacturer.

The cheapest spring is the fabric or

woven-wire type. It is also the poorest on which to sleep. It is called the fabric spring because it is made from wires which are slightly coiled and woven as a cloth fabric would be. Cribs, baby beds and youths' beds are commonly made around this type.

It can be recommended for the crib or child's bed, if an especially soft mattress pad is used on top of the fabric spring. The fabric spring is not fit for human use, however, for persons who weigh more than 40 pounds. It does not conform to the body surface and it quickly develops a permanent sag, even when the bed is not occupied, a sag which can not be removed by tightening it at house-cleaning time the way grandfather tightened the old rope bed.

The link type of spring is usually moderately priced and has only fair sleeping quality. Being made from links of stout wire which are joined together, end on end, it received the appropriate name of a link spring. At the two ends this linked net is fastened to the framework by stout springs. Sometimes a few springs are used to attach the wire net to the edges of the frame.

What we sleep on in such a spring is, of course, taut wire. This has the same weaknesses as the fabric spring, but it usually does not sag as quickly when there is no weight in the bed. It does sag, however, when some one is in the bed. This is the spring type which is most widely in use at the present time—though it is essentially the same as the bed of leather thongs invented by the Greeks. Wire is used in place of leather.

During the Philippine insurrection narrow link spring beds with folding head and foot, such as many people use to-day on camping trips, received an unusual nickname which still persists. Distressed at the apparent discomforts of our soldiers, who had to sleep on the damp ground during the campaigns, an American woman, who spent the more important part of her life in the Orient, bought a shipload of these simple folding link spring beds, which were rushed to our boys. This woman was Helen Gould. And beds of this type are still known as Helen Goulds.

The most restful bedspring is the coil type. This was devised by James Liddy after his first work with ordinary buggy springs. It is appropriately named from the large number of vertical coil springs which are fastened together in various ways to give a sleeping surface which readily yields where most pressure is placed on it. It conforms to the body surface and body build of the sleeper, supporting rather than bending the body. If well made, it will not sag. Not all coil springs are the same; the size of the wire, diameter and shape of the coils, the number of coils, tempering and the methods of fastening the coils to one another all modify the stiffness or springiness of the completed bed foundation.

After one's first birthday, one should sleep on no spring but the coil type. As body build and weight change from decade to decade, changes may be necessary to secure a foundation which has the proper resiliency to take care of increased weight or altered distribution of weight. At ages of 8, 18 and 38 it is often wise to change the bedspring, just as the size of the pillow needs to be changed between the ages of 1 to around 15 or 16, the period when shoulder breadth makes marked changes.

The mattress and spring together, of course, give the buoyant quality—or lack of it—to our sleeping place. A "soft" mattress is needed more on the fabric or link spring than it is on the coil spring. What we should do is to start with a good coil spring and then find the mattress which gives the best sleeping comfort for the individual who is going to use it. This can be done only by lying on it—

and yet most springs and mattresses are unfortunately bought in the grab bag.

Use these tests to discover the right combination:

Do you sink down comfortably, and without a sag at the hips when you lie on your back?

Does the combination of spring and mattress remain somewhat firm so you can turn easily from the back to the side?

When on your side, does the shoulder settle in comfortably without twisting and without pressure?

Can you place the downward arm almost anywhere with comfort?

Does your hip sink down without your back sagging downward or being thrown upward?

Those things rather than sentiment or appearance should determine the value of a bed. Sentiment changes, but the basic rules of sleep persist. In 1858 two candidates debated in a small Illinois town. The dusty square was packed, bands blared "Oh, Susanna," and twelve-pound cannons saluted the arrival of one candidate on his special train. The other candidate, gangling and awkward, arrived, unsaluted, on the stage-coach. Seventy-five years later the beds on which these candidates spent that night were auctioned. The one occupied by Stephen A. Douglas brought $1.25. The bed Abraham Lincoln slept in before the debate brought $20.00. Beds and speeches both have endured. But to-day they make better beds.

The history of sleep to-day is being written on tapes in various laboratories, by automatic instruments which make an indelible record of turnings and tossings. As you write the history of your own sleep, I hope the accounts I have given you of how other people slept will make the history of your own sleep a chronicle of a Renaissance and not of a Dark Age.

Be an heir of the past, not a slave of it!

A PETROGLYPHIC STUDY OF HUMAN MOTIVES

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Our title may seem to be as paradoxical as a "round square" and as futile as "frozen assets." Petroglyphs imply something stony and static. Motives in execution are fluid processes. Yet petroglyphs, like all finished works of man, are in a very real sense "fossil" motives, and can be used as one help in revealing what the living organisms were like.

This is a study of motivation. It does not contemplate a survey of the problem in all its aspects. Conscious motives for human behavior are innumerable and complicated, often obscure and ill-comprehended even by the doer, not easy to reduce to a few simple principles. Both the popular and the scientific observer of actions is subject to a temptation to recognize too few of the possible motives from which they may spring. One good approach toward understanding them is to limit consideration to a particular class leading to a single type of action and result, while acknowledging but not studying the many others which are effective in other situations. By such definite limitation to one or another of the objectives of human action, studied separately by investigators who can master the limited fields and come to a comprehensive understanding of the factors operative in them, we may hope eventually to unravel the intricacies of purposive motivation in general. There must be a slow accumulation first of clear knowledge about all types of individual cases.

Essentially, the problems of motivation are not resolvable completely in the psychological laboratory. Some ranges within its vast extent may be explored there, but not the entire field. To comprehend the intricacies of behavior, vision must not be limited by the walls of the workshop, but must aim, astronomer-like, to roam over the wide universe of action and accomplishment. The circumstances involved in the varied and un-imitable situations of actual living require study.

Moreover, in essence, these problems can not be approached by objective methods. What any one truly feels and desires and what he truly aims to accomplish may be inferred sometimes more or less accurately by the outside observer, *after* knowledge of subjective conditions and their objective expressions has been gained. It is only the feeler's and actor's own consciousness and trained introspection which can primarily supply any least inkling of what is going on as causative processes. However exact we may come to make our knowledge of "action currents" in functioning brains, these can never be interpreted as to their full significance except in the light of such introspective revelations. Introspection, but no more fundamentally than objective observation, may be subject to uncertainty and error. This is no more true in the one case than in the other, and there are criteria for evaluating the dependability of either of them. Both must be used and correlated. When we are equipped with well-trained introspective insight in regard to the inner happenings in a given field of thoroughly studied endeavor, we may then feel assured of having good grounds for acceptable inference from objective reports or records dealing with the same type of occur-

rences. The objective facts in this field are uncomprehensible and valueless except in the light of enlightened introspections already correlated with like objective facts.

An interest in petroglyphs has been forced upon the present writer by circumstances, and has led naturally to a consideration of all the kinds of motive which might have led to their production. One case in particular has been studied with especial reference to this problem. It does not exhaust all possibilities of motive that may have been causative factors in other cases with other content. So far as these others have been studied by the writer, their contribution to the problem will be considered. But there is no attempt to widen the field into a completely exhaustive inquiry.

Wide interest was aroused by the discovery in 1926 of a runic record on Noman's Land, a small island just south of Martha's Vineyard. The rock on which it is engraved lies on a boulder-strewn and storm-swept beach and bears the inscription "Leif Eriksson" in unmistakable runic letters and the date "MI" in Roman numerals. Opinions differ in regard to who carved it and when it was done. The writer's own opinion is that it was the work of some one within the present century. But other writers have expressed different beliefs. One attributes it to Leif himself or his Norse followers, and another to some later explorer of our coasts at some time within the sixteenth century.

Our problem is that of what might have been the motive of the unknown person who made the record, without consideration of the question about when or by whom it was done, at any time from the date of Leif's voyages down to the present. Looked at in this manner, we must admit the possibility of any one or a combination of a wide variety of different reasons for making the inscription. Other motives than these might operate in other cases. For a record with this particular content, we may rationally consider any one in the list which follows as one which under certain circumstances might have led to its production. For this purpose, we are assuming that we know nothing about it, which makes it impossible to entertain the idea that it may actually be of any age which the assumption of any particular motive demands.*

Both of the writers who argue against a recent date for the inscription assume that if it were made recently it would have to be regarded as a fraud, a fake, a hoax, a deliberate attempt to deceive. Here are a few of their expressions: "It is most unlikely that they (later persons) would have forged an inscription in such an inaccessible locality where there was such small chance of discovery. . . . It is out of the question for anyone who has ever seen the inscription to say that it is a later day 'fake.'" "The would-be perpetrator of a 'practical joke' would scarcely—unless possessed of an abnormally fine sense of artistry—leave it at a place not likely to be visited by observing persons, and at a spot where the chances are that the 'bait' would be invisible owing to the tide. . . . Anyone who would have taken the trouble to carve the inscription since 1837 would presumably have also undertaken the much lighter labor of first consulting a reliable reference book on runic lettering in order to get his lettering correct if he hoped to impose on the credulity of others."

This seems to be the usual attitude of people who discuss the matter casually. The writer meets it constantly. Almost every one says that if it was done re-

* This assumption is made for the purposes of this discussion only, in advance of inquiry into the actual facts. What the latter reveal, if anything decisive, is considered in a separate report upon the inscription, soon to be published in *The New England Quarterly*.

cently, then the thing is a hoax or a practical joke. This is altogether too simple a way to dispose of the question of motive. On discovering such a record as this, one might think of many possible reasons for its existence so long as he had not yet secured any decisive information making one or others of them inapplicable to the particular case. Some of them may seem very unlikely; some are closely similar to others, yet with a distinctly different nature as motives. Their enumeration is a question merely of the psychological possibilities, and one must consider all of them in order to judge the problem fairly. Such an inscription as this one, then, considered apart from the question of its actual origin, might exist conceivably as a result of the working of any one of the incentives in the list which follows.

(1) Desire on the part of an explorer to leave his signature, executed by himself or under his direction, as a record of first discovery; with or without the additional aim of claiming the territory for his own nation. This is so familiar a procedure that there is no need to dwell upon it. Flag almost always, a more enduring record often, is left by the discoverer of new lands. The Portuguese, for example, who at one time were the most active of the explorers of unknown regions, frequently erected a padrão, or stone pillar, suitably engraved, at prominent points. Somewhat similarly, early cartographers attached to their maps of newly found places a simplified representation of the flag of the country claiming the honor of discovery.

(2) In some cases the aim of the explorer might be to leave his name thus engraved, set up prominently in some conspicuous place, as a landmark for the guidance of future voyagers. In the days of Vinland exploration, when compasses were unknown and sailing-directions—if we may judge by what is retained of them in the Sagas which have come down to us—were extraordinarily inadequate, some such means of positively identifying a place when reached at last would have been useful. If Leif himself was the author of our inscription, and realized that others would be sure to wish to colonize the attractive land where he had erected his "Leifsbooths," he might well have been moved by this consideration.

(3) It might have been the work of a crew, shipwrecked in a remote and little visited region, who desired rescue and thus sought to attract the attention of any who might come in search of them. It might then serve also as a record of their fate, in case no rescuing party came in time. This would not apply in our particular case, for we know that nothing of the sort happened to Leif Eriksson. But if we did not happen to know that, this would be a motive that would have to be considered. In all probability it was the one which led Miguel Cortereal to carve his name on Dighton Rock in 1511. It is analogous to the flag of distress or the bonfires or the rifle-shots of numberless people lost in remote places.

(4) The moving impulse might have been none other than that common one which has led innumerable people, of all races and in all times, to write or carve their names or initials or personal symbols in prominent places everywhere. The world is full of such devices, often unhappily defacing the objects whereon they are recorded. Pencils, jackknives, chisels, flints, are and have been thus busy in almost every place where people congregate. Precious relics of the past are not infrequently desecrated and even utterly spoiled in this manner. Among other valued monuments, our own inscribed rocks often suffer this fate. Sometimes it is a more harmless diversion, when the recording surface has no value in itself. This was true, for in-

stance, in case of the ledges at Pipestone Quarry in Minnesota, where "it was formerly a custom for each Indian who came to the vicinity to transcribe his totem upon the rock."[1] It was true also of the once famous "Written Mountains" in Arabia, whose rocks and cliffs are generously engraved with "ancient unknown characters." These were exciting deep interest and speculation during the early eighteenth century, when it was widely believed that they were historical records of great importance, perhaps a confirmation of the wanderings of the Children of Israel in the wilderness; but it is now known that they were utterly trivial, such as names of passing travelers.[2]

This impulse to leave some personal record of one's passing, with no such object as is implied in our previous cases, is a form of ego-maximation, a gratification of the urge to attain some kind of prominence, even an easy and trivial one. It takes the most varied forms, of which initial-carving is only one. It may be a mere normal and idle whim; or it may be a form of compensation for inability to attain success and prominence in more worth-while ways. We see it manifesting itself in silly "showing-off," in contests for pie-eating or pole-sitting championships, in attracting attention and service by becoming an "interesting invalid," often entirely without realization that that is the only reason for one's illness. These tendencies, mild or exaggerated, normal and harmless or abnormal in outlet, are deeply seated in human nature. It could have been this kind of incentive which led to the making of our particular record.

[1] Garrick Mallery, in 10th Annual Report, Bureau of American Ethnology, 1888–9, p. 87.

[2] See heading "Sinaitic Inscriptions" in Biblical encyclopedias; or a summary by the present writer in Publications of the Colonial Society of Massachusetts, Vol. XVIII, p. 268, 1917.

These four are alternative possibilities any one of which might have been the reason leading a person to carve his own name or to have it done for him. All the others in our list will apply to cases in which the name has been carved by some one other than the person to whom it belongs. The first group of them to be considered may all be classed under a desire to deceive, to perpetrate a fraud or practical joke. But the particular reason for it might vary; and it might be attended by a hope that the fraudulent record would be publicly and permanently accepted as genuine or it might be of a more private and temporary character.

(5) The incentive might be a hope for personal profit, through increase in the sales-value of the land where the inscription lies, because of the glamor thrown upon it through its connection with romantic episodes or rare objects regarded as precious. The maker of fraudulent antiques which he sells for profit is of course one of the commonest examples of this type.

(6) The only reason for deception might be a desire for enhancement of personal importance and pride because of ownership or other intimate connection with a place so renowned. Mere ownership of fraudulent objects of the most varied kinds, so long as they are accepted by intimates or visitors (not necessarily by experts) as genuine, may often give rise to this kind of satisfaction.

(7) The desire to manufacture evidence for an ardently held belief is a not uncommon manifestation. It runs through all varieties of practice based upon the idea that "the end justifies the means." Religions have been founded upon, or supported by, false documents and pretended revelations. "The forging of ancient documents and inscriptions to prove some contested or desired point is a well-authenticated matter of

modern history.'"[3] Scientists and other scholars have sometimes reported actually unmade discoveries, or have distorted history, in consequence of this urge. Naturally, they may do it also, not for this reason, but for those previously considered—for personal profit or prominence, or because under a dictatorial society only thus can they gain a livelihood and care for loved ones. But they may be tempted by this more unselfish passion to defend a truth. In our particular case, if this had been the motive, the aim evidently would have been to settle the popularly appealing and disputed problem as to the location of Vinland.

(8) The inscription could have been the result of pure malicious delight in deception, with no possible gain or discoverable satisfaction to the perpetrator except that of secretly gloating over his success in fooling a gullible public, or that of gaining repute as a successful practical joker in case he later discloses the truth. This is a motive that is surprisingly often influential. There are numberless instances of such apparently purposeless hoaxes on record.[4] Examples of them seem to be furnished by the unaccountably numerous fraudulent inscriptions and antiquarian relics turned up in America, whose fabricators, so far as known, never profited by their deceptions;[5] and by the inscribed implements and pottery unearthed at Glozel in France in 1924, which seemed at first to prove that men of the stone age developed the first linear alphabet some ten to twenty thousand years ago, but which have since been declared by scientific committees of investigation to be recent frauds.

(9) Closely akin to the last-named motives, but differing in its psychological character, is private and temporary, as contrasted with public and permanent, hoaxing. It may take the form of a practical joke with serious consequences, or it may be the result of a delight in entirely innocent mystification, in having fun through the temporary puzzlement of family or friends. The amateur prestidigitator is moved by this widely influential impulse. Apparently the great wave of modern spiritualism started with a similar innocent attempt on the part of the Fox sisters to mystify the members of their family, with such unexpected success that it became impossible for them to acknowledge their own responsibility for the phenomena until many years later, when it was too late for the confession to arrest the progress of the cult which had its origin in their childish pranks. It is easy to find printed accounts of examples of this not uncommon practice. Ghost pranks not infrequently have this nucleus, and many other types of practical joke. One of the most extraordinary cases on record is the "colossal scientific hoax" of which Dr. J. B. A. Beringer, of Wurzburg, was the victim. Knowing his peculiar views about the nature of fossils, his colleagues and friends prepared a large number of ingenious fabrications of clay, including incredible fantastic shapes of insects and

[3] R. V. D. Magoffin and Emily C. Davis, "The Romance of Archeology," p. 152, 1929.

[4] See P. T. Barnum, "The Humbugs of the World," 1866; J. A. Farrer, "Literary Forgeries," 1907; D. G. Brinton on "The Curious Hoax of the Taensa Language," in Essays of an Americanist, 1890. In the Report cited above, on page 759 Mallery recognizes this motive of "amusement derived from hoaxing" or of "simple mischief"; and speaks also of "craving for personal notoriety" (our No. 6), and of "schemes to increase the marketable value of land" or to sell the fraudulent articles (our No. 5).

[5] A brief survey of some of them is given by M. M. Quaife, in *New England Quarterly*, 1934, Vol. VII, pp. 638*ff*; and another by E. B. Delabarre, "Dighton Rock," 1928, Chap. XVI. The long puzzling "Grave Creek Tablet" has been deciphered, according to *Science News-Letter*, May 24, 1930, as being written in ordinary letters purposely distorted almost beyond recognition, and reading: "Bil Stumps Stone Oct 14 1838."

animals, and tablets on which were geometrical figures and inscriptions in Hebrew and Arabic. These they buried in the ground for Beringer to dig out. The learned professor published a sumptuous book in 1726, in which he used these remarkable discoveries to support his claim that all fossils are capricious fabrications of God, implanted in the earth for some inscrutable reason, whether for his own pleasure or to test the faith of men. When the fraud was exposed, it is said that Beringer died of a broken heart.[6]

Our last five cases have dealt with different types of incentives that might result in deliberate fraud. That they do not form the only alternative to the four earlier cases, in all of which the inscriber himself is assumed to have recorded his own name, we are now about to establish.

(10) Desire to make a purely scientific experiment, by producing a mysterious inscription and seeing to it that it gets discovered, aiming only to learn whether the puzzle can be solved and how the scientists go to work to accomplish it. Perhaps there are no sure examples of the use of such a method, but it must be listed as among the possibilities.

(11) Idle amusement; engaging in an interesting occupation to "while away" a time of leisure or of waiting. This is a natural impulse in active men, and it need not be complicated by any thought of whether the work will ever be seen by other persons, or what impressions it may make upon them. Given some one having a keen interest in the Norse discoveries, present on Noman's Land for a day or longer for any reason whatever, with nothing else to do for a time, uneasy to be doing something to keep himself occupied, one thing that might well have appealed to him could have been the carving of this inscription. He might have been waiting, for instance, for companions otherwise engaged to be ready to go home with him; or for favorable tides or times for fishing or for shooting game; or during intervals between times when he had regular duties to perform, such as engaging in construction work for the owner of the island or such as making surveys or taking tidal or other observations for the government; or he might have sought merely for some interesting occupation while he stopped at the island for several hours as an incident in a sailing trip, possibly by himself alone. Under any of such circumstances, the preference of a great many of us would be to be occupied in some active way rather than to pass the hours in idleness. The time required for making this inscription need not have been longer than a fairly long mid-day when the tide was low and the sea was calm. Such a motive as this was responsible for certain inscriptions on the coast of Maine, which James Phinney Baxter reports as having been made by "boys at play"; and, in the opinion of many authorities, for many of the inscriptions made on rocks by Indians. Grown modern men might enjoy a similar occupation.

(12) A playful impulse to act out the story of the Norse voyages, in the course of which, among other scenes enacted, might be one in which the hero carves such an inscription as he thinks might have been appropriate if Leif had actually done the same thing when he was here. Even grown men, as well as children, sometimes delight in such games. This is one of the possibilities that is worthy of consideration. Children love to play pirates, explorers, Indians; and adults who are fond of children often love to join them. With no children participating to give them an excuse, grown men still carry on similar pre-

[6] L. A. Gausman, "The Figured Stones of Wurzburg," in SCIENTIFIC MONTHLY, 21: 515, 1925.

tenses among themselves in their hours of recreation. The members of one of the earliest week-end country camps in the picturesque wilds of southerly Rhode Island constructed a "Druid's Stone Circle" in which to hold ceremonious meetings. In their numerous fraternal organizations, men often call themselves "Red Men," "Knights" and other heroic figures. They clothe themselves in imposing regalia, adopt high-sounding names for their officers, conduct mysterious rites and initiations and guard deep secrets with utmost care.

Play, pretense, pageantry, dramatization—these have strong appeal throughout life for a large proportion of people. When the more serious concerns of life are laid aside, they are enjoyed in widely varying forms on appropriate occasions. Such might conceivably have been the motive for our inscription. Rafn's belief that Vinland was located in this region became known here in 1837, and ever since there have been numerous people fascinated by the idea that the Northmen discovered these shores. Many summer visitors to Martha's Vineyard and other near-by places have certainly shared in this enthusiasm, and some of them surely have possessed an easily acquired knowledge of the forms of runic letters. Many of these visitors hire boats for fishing excursions or to enjoy a day's sailing. At any time since 1837 some such party may have sailed over to Noman's Land and, in a holiday spirit of fun, play and adventure, may have amused themselves by dramatically reenacting Leif's voyage of discovery. They might have made it realistic by pretending that they were Leif himself and his companions, and have carved such an inscription as they would like to have had him leave behind. We can easily imagine some such incident, innocent of any thought of deception or of mystifying those who might later see the rock.

(13) If we knew nothing of the subsequent history of the person whose name we find thus engraved, it might be a sepulchral monument erected by his companions. We do happen to know that this can not be true in this particular case. Yet it may well be included as something to suspect in case of unexplained inscriptions of this type.

(14) The urge to erect memorials to great events and heroes of the past. The world is full of the most varied forms of the working of this urge. They include not only monuments and inscriptions, but memorial days. Examples closely pertinent to our inquiry are the statues to Leif Eriksson in Boston and to Massasoit at Plymouth, and the boulder dedicated to King Philip on the summit of Mount Hope in Rhode Island.

But there are private as well as public memorials of this sort, the result sometimes of a passing impulse, without intention that they should involve permanent and public recognition. There are two examples of this sort in Rhode Island. One is a rock inscribed "To the Memory of Wawaloam, Wife of Miantinomi, 1661," on a private estate in Exeter. The other is a boulder near the foot of Mount Hope, inscribed in Cherokee characters and Wampanoag words to the memory of "Great Metacomet, Chief Sachem," and executed probably about 1834 by a half-breed Cherokee who had a Wampanoag wife.

Our rock on Noman's Land never was the scene of a public tribute. But it might well be a private memorial, the expression of some one's genuine admiration for the bold explorer whose name it bears, unattended by any suspicion of a desire to deceive any one. In such case, no matter when it was done, it would be unjust to call it a fraud or fake. This is the motive which one writer, attributing it to an explorer of the sixteenth century, believes to have been responsible for our inscription.

But even so, it does not by itself help to settle the time when the work was done. The author might have been some member of one of the Norse expeditions following that of Leif; or an explorer around 1500 or 1600; or, just as well, some one within the last one hundred years.

(15) The possibility of a mixture of these motives is not to be lost sight of. Nor must we forget that some other motive that has not occurred to us may have been the influential one. Two recent writers of crime fiction have made their detectives say: "In almost every case there may be motives so deeply hidden that the most skilled investigators would never discover them"; and "Until psychiatry learns to take into account all the quirks of human motive, crime detection will remain an infant science." We are not concerned here with any implication of crime. But these testimonies to the existence of undiscoverable motives are very pertinent to our problem. There are many alternatives to a "hoax" explanation, if our inscription was not the work of Leif Eriksson himself. It is no part of our purpose to decide the question about which one of them was actually the effective one. Our only aim has been to survey the entire range of psychological possibilities. Yet, having stated already that it is the present writer's belief that the inscription is recent, it may not be without interest to add that he thinks it probable that the motive for it was that which we have numbered 14 in combination with the one numbered 11: a genuine private tribute, at a time of leisure which the author of the work, filled with enthusiasm for the old Norse heroes, preferred to fill in with an active and interesting occupation. The reader is asked, however, to forget that, to assume that there are no indications about when or by whom it was done, and then to recognize the entire list of motives as applicable.

If we should broaden our inquiry, we would find it necessary to extend our list indefinitely. To keep it within bounds that might permit a reasonably exhaustive survey of possibilities, we have limited our task to consideration of a single type, especially of a single stone with particular inscription whose origin and date are open to legitimate controversy. We are not now tempted to cover the entire field of motives for making other inscriptions with similar thoroughness. It will help to give a desirable perspective and setting to our limited problem, however, if we enumerate without exhaustiveness some motives that must have been the occasions for other types of petroglyphs.

On New England rocks, the writer has found Indian carvings that almost beyond question were meaningless haphazard scribblings, the product of an impulse to be active anyhow, as some people slash at shrubbery in passing; further encouraged, no doubt, by finding that their artistic efforts aroused the interest and admiration of watching companions. In some cases, probably, such childish scribblings might be the result of an endeavor to imitate, without knowing how, the white man's marvelous art of writing. In other cases, ornamental and geometrical designs are carved, still without meaning, but satisfying an urge for more pleasing artistic expression and eliciting greater applause from the onlookers. The wide-spread urge to make crude pictures of familiar objects, men, animals and trees, is also evident, again due to both motives and still having no wider meaning. Beyond this it is possible, but never certain, that attempts are made to record individual and tribal adventures; they could never be read as such without instruction from the individual recorder, or similar sure clues. Some series of marks might well be arbitrary mnemonic aids to remembering the succession of words in a song, or the stanzas of a magic formula that was

believed to aid, for instance, in securing game or other desired ends; but again, to be sure of this, we would need to have outside information of some sort not often or easily acquired. In all this, as yet, there is no true symbolism. Yet this gets reached at last, in this New England region, in a few cases under influence of contact with Europeans and Colonists. There are a few fairly surely identifiable individual signatures in the form of such "marks" as Indians signed to deeds; or of tribal emblems; and uncertainly of some simple designs that may have had a religious significance. There are known only one gravestone, one rock and one bannerstone in all this territory which appear to give evidence that Indians, after long contact with white men, had begun to evolve an ideographic or syllabic system of writing that was used in one case to mark a grave, in another to pay a tribute of admiration for a hero of the past, and in the third to indicate personal possession, expressed in definite words. There may have been other types of marks, and other ideas expressed, but we have no means of being sure of this. Even pictographic writings, commonly supposed to have been characteristic of Indians, are wanting in New England except in case of a very few possible indications of directions for travel, or some very few other indecipherable and uninterpretable cases. Other inscriptions in New England, not due to Indians, fall within the classes of motives already recognized, except one. Religious exhortation to lead a more pious life has been the motive for both painted and carved writings, in English, on some Rhode Island rocks. Similarly, instruction in the mysteries of an occult religion was suspected, mistakenly, by Moreau de Dammartin as having been the aim of Egyptian priests in carving Dighton Rock.

Many writers attribute carved or painted figures of animals or plastic representations of them, in America and elsewhere, to the belief that thus magic power is gained to secure them as game. In still other cases, more definitely religious ideas are assumed, such as the propitiation of higher powers, or expressions of gratitude to them. In one well-argued case, the carvings are believed to be the record of a Great Adventure performed by daring individuals who braved the dangers from guarding spirits of a difficult descent into deep recesses where salt might be obtained. Those who believe in the authenticity of the Kensington stone in Minnesota and of the Kingiktorsuak inscription in Baffin Land, and many others elsewhere, look upon them as similar records of great adventure.

These last considerations suggest only a few of the motives that may have been causes additional to those mentioned in our own selected single case. Doubtless many more might have been discovered. For the one case, at least, we have attempted to survey the possibilities as exhaustively as we could.

THE NEW ORDER OF THINGS

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As I meditated upon the subject of my address[1] to you to-day, there came to me a vision of that period a few decades ago when I and my companions stood, as you stand now, at the threshold of life, each with our story of the world as it had been handed to us and with our little kit of tools, mental and spiritual, designed for the tasks ahead of us, and fashioned according to the principles of our teachers.

For those who chose the paths of science, the outlook was melancholy indeed, for within the period of our own studentship one of the wise men of our calling, looking into the future and seeing naught but barrenness, had uttered his belief that active science had come to an end—that there was little more to do but repeat the investigations of the past with new, but not over-exciting refinements, as one would play and replay the music of the old masters with ever a little more attention to refinement and detail.

The science of electrical engineering had become established upon firm foundations. Public buildings were lighted by electricity, and certain wealthy people had even gone to the extravagance of installing this expensive method of illumination in their houses. Electric street cars went all over the city, but were still a source of wonderment. Even one of my teachers who had taught me about these things ceased not to marvel that the influence responsible for carrying the car up the steep hills of the town could travel along a relatively insignificant copper cable.

Not many years earlier, as a boy, I had witnessed a truly remarkable phenomenon of a hundred or so automobiles, which under the guidance of certain hardy and venturesome individuals had set out to make the journey of fifty miles under their own power from London to Brighton. The few which arrived seemed to be on their last legs as a result of the ordeal. Clattering along with many and diverse noises, explosions, squeaks and rattles, they had demonstrated that the thing could be done. I often think of the consternation which would have been produced in the mind of some citizen of sixty years ago if he could have been transplanted for a moment in time so as to catch a glimpse of a modern automobile. I can imagine his returning to his own epoch and telling the story to his friends in such words as these:

I have had a most disturbing experience. I met a man—he assuredly must be a madman—who showed me a curiously shaped thing which was somewhat like a wagon of no small weight, but instead of having strong substantial iron tires, the thing stood on four rubber tubes blown out with air. It was a most ridiculous contraption because, obviously, the rubber tubes must wear out before the thing could travel a mile. But the most fantastic feature of this contrivance concerns the manner of its propulsion. We all know that gasoline vapor and air form a most dangerous mixture, which, when ignited with a spark, explodes with great violence. Well, this strange vehicle was driven by a series of such explosions which took place within its interior and were somehow arranged so that they did not blow the machine to pieces. I asked the inventor of the vehicle how the occupants could tolerate the terrific bombardment and shocks which must be incidental to its propulsion. When I tell you that he informed me that the shocks and noises were inappreciable, you can judge for yourselves as to his sanity, the more so since no sane person would build a contraption based on principles which at the best must result in the whole thing shaking to pieces in no time at all.

[1] Delivered on June 10 at the commencement of the University of Florida.

But outstanding as are the changes which have resulted from the development of engineering skill and from the utilization of the discoveries of the last century in the field of engineering and electricity, they are as nothing compared with those changes which have taken place in our mental vision of that physically invisible universe of the atomic kingdom whose laws control, ultimately, all the phenomena which present themselves to us in our everyday affairs of life.

There are periods in the progress of science when nature seems to present a great barrier to further vision. The phenomena which are the subjects of our interest seem to divide themselves into two classes, those concerning which we know everything that it seems worth while to know and those of which there seems no hope that we can know any more. Forty years ago physical science found itself in this state. The coarse-grained laws of matter had been well fathomed. We had evidence that matter was composed ultimately of very small things, atoms and molecules; but it seemed as though, rich as might be the story of these small things, it must necessarily be a story hidden from us forever. And so, the sage of our calling, whom I have cited earlier, offered his famous dictum whose meaning was that discovery was ended and that science was dead.

It was true that we were compelled by logical argument to believe that even coarse-grained phenomena presented by matter in bulk were somehow or other determined by the properties of the atoms of which the matter was composed, but there seemed little hope of extracting through an examination of those crude phenomena anything like a complete story of the inner workings of the atom. We were like the ancient Britons ruled by Rome. That which happened to them was determined in some way by the structure and government of Rome, but most of the richness of Rome was bound up in itself and had but little bearing upon the external empire. That empire felt the power of Rome only as an incidental side-activity of that power. Then, science was startled by the discovery of the electron, a fundamental element of the structure of the atom. This was a great encouragement. It was as though the barbarians had found that Caesar lived not always in Rome, but occasionally went abroad. Might it not even be possible to kidnap this Caesar of the atom and make him perform for us barbarians that we might learn of what metal he is made? Then before long, tempted forth by the activities, of whose drama the barbarians had made Caesar the chief actor, came Caesar's consort, the proton, to dance in the revels of a life free from a mere atomic existence. Free from the monotony of this existence, Caesar found new powers of which he had never known before. He could be made to run with great speed, and by his own individual energy to cause light to flash forth from that which he struck. This Caesar of the atom, the electron, could, in fact, eject ultra-violet light from metals with which it collided. When excited to great energy it could create x-rays in crashing through the atoms in which it had formerly reigned as king with little to do but carry out a conventional routine.

For more than a decade, physicists hoped to have found in the electron and the proton the two fundamental bricks out of which all the architecture of nature was fashioned. Having found the bricks, man was encouraged to see what kind of structures could be built of them. From his investigations of the properties of these bricks he had come to some conclusions as to their nature. The electron was a thing so small that if we should magnify its diameter so that it attained the size of a piece of small lead shot, that piece of lead shot would, on the same scale of magnification, become larger than the sun. The mass of the electron was so small that if we should

magnify all masses so that the electron attained a mass of one tenth of an ounce, that one tenth of an ounce would, on the same scale of magnification, become as heavy as the earth. The proton was found to be two thousand times heavier, but two thousand times smaller than the electron, so that if we should magnify such a proton to the size of a pin's head, that pin's head would, on the same scale of magnification, attain a diameter equal to the diameter of the earth's orbit around the sun.

It is characteristic of mankind to try to fashion the new upon the model of the old; and so in building pictures of the atom out of electrons and protons, the hope was to make the mechanisms in those pictures something like the mechanisms of everyday experience. The physicist would have liked to picture the atom as a kind of complicated watch or a special kind of dynamo or as a little solar system or a conglomeration of springs, something, in fact, with which he was already familiar; and he hoped to extract out of the models of this kind characteristics which could represent the atom.

One of the most characteristic features of matter is exhibited when, in a gaseous form at reduced pressure, it is caused to emit light under the influence of an electric discharge sent through it. Under such conditions it emits light of definite colors characteristic of the gas. For many years, science had recognized the fact that the secret of the explanation of these colors was, somehow or other, to be sought in the nature of the atomic mechanism producing the colors. The first thought was that the electrons in the atom were constrained to move in complicated vibratory motion when excited, like a lot of balls connected by springs, and that the motions communicated themselves to the surrounding medium, the ether, which was supposed to permeate all space and serve as the means of transmitting light and heat from the sun and stars. The different kinds of motion of the atomic springs were supposed to correspond to the different colors of light emitted by the atoms. Alas! it was soon found that this kind of picture would not fit the facts, and the trouble was that nothing like it could be made to fit the facts. All sorts of modifications of the details of these mechanisms were imagined, but there was something in all of them which ran just contrary to what was required to correspond to the observations. The unfortunate thing was that the characteristics of these models which were most unsatisfactory for the purpose in hand were just those characteristics which made them most pleasing to the mind as intuitively understandable models. It is as though we tried to understand certain of the features concerned with the building of a bridge by thinking of the bridge as built by artists. Perhaps the features concerned are those having to do with the letting of contracts and the administration of matters pertaining to construction. We find it difficult to picture the artists as doing these things; and if we modify the characteristics of the individuals so far as to make them fit the duties required of them, we find we can no longer think of them as artists. If one is sufficiently sophisticated he can claim that an artist can also be a good executive and business man. I do not deny it, but, if the picture of an artist which you have formed in your mind is that of a being to whom these activities are foreign, you can not retain these characteristics in the picture and yet have it satisfying to you. At least, you can not do this unless you decide not to think too much.

When it became quite clear that no kind of model built on the lines of concepts which were familiar to us could be a satisfactory representative of the atom, we reluctantly accommodated ourselves to a new philosophy in the theory of the atom devised by Niels Bohr. In this

theory there was a compromise. The atom was half model and half something else. We came to think of the atom as a little planetary system. At the center was a nucleus containing all the positive electricity of the atom and most of its mass; and around this nucleus electrons revolved according to the same laws as those which govern the motions of planets in their journeys around the sun. But now it was necessary to suppose that this atom had certain additional characteristics which the ordinary laws of a planetary system would not require; and, worse still, it was necessary to suppose that the atom would do certain things which a strict interpretation of the planetary laws would really deny. Only certain of the orbits which would be permitted by the planetary laws were allowed in our picture and no reason was given for the exclusion of the others. Then it was supposed that the electrons could jump from one possible orbit to another and emit light in the process; but no reason for this performance was given and no detailed story of what happened during the performance was told.

When the man of science tries to speak of these things to the layman, it is difficult to do so without conveying the impression that he, the man of science, is ultimately a hopeless lunatic building castles in the sky. In order to avoid complete surrender to this accusation I must beg you to believe that in this theory of Bohr there is something else. There is a foundation of a consistent set of rules or laws for the behavior of the atom which contain in themselves the power to predict much that occurs. There are in fact two things. There are the system of rules and the model. The model, it must be admittted, is terribly unsatisfactory. The more we think of it, the worse it is; but the rules which go with it are perfectly definite.

One may well argue: What is the use of seeking an explanation of the behavior of the atom by setting up a set of rules which are chosen for no other reason than that they harmonize the facts, and which contain no other reason for their existence? The point here is that the man of science tries to reduce the number of his rules to a minimum. The facts of nature and those associated with the atom in particular are many. The man of science seeks some way in which by stating a few principles he can make those principles the keynote of all the rest. Then he can understand all the rest *in terms of those principles*, even though he may not understand the reason for the principles.

The man of science seeks a way in which, by postulating a few things, he can deduce as their consequence many things which are found true to nature. The classical example of this method is found in Newton's formulation of the law of gravitation. I will not remind you of what the law of gravitation is, further than to state that in it Newton stated one thing about the motion of the heavenly bodies, and from that one thing it was possible to deduce all the consequences of classical astronomy. It was possible to calculate the shapes of the orbits of the planets, the time of occurrence of eclipses, the time of return of comets, the relation between the periods of revolution of the planets around the sun and their distances from the sun. These and a hundred other things it was possible to calculate from that one statement embodied in the law of Newton.

When I strike this desk, I produce very complicated vibrations in it. Probably no mathematician living could calculate all the details of those vibrations because of their complexity; yet I feel that I understand those vibrations, because I believe that nothing but complexity of mathematical calculation exists between the complete story of them and one or two very simple laws concerning the way in which the motion and the shape of a little cube of wood respond to forces applied to it. It may sound

rather strange to say that the physicist likes to take a simple thing and make it complicated. Yet that, indeed, is one of his main activities. He likes to grow out of simple things a complexity which corresponds to the complexities which he observes in nature. Then he can feel that his understanding of the complex is reflected back to his understanding or acceptance of the simple.

And so the main feature of this theory of Bohr was that in terms of a few simple assumptions much of the story of what was observed in the doings of the atom could be deduced. What remained as a model in that theory was a sort of half-hearted attempt to seek comfort in believing the few simple things by hoping that some kind of reason for them could be provided by the model. The irony of the situation was that the parts of the model which had the greatest pictorial significance were just those which played no part in the story of the atom's activities. It is as though in trying to represent the characteristics of a certain animal, I hit upon the idea that perhaps he was an elephant, but found that in order to explain his activities it was necessary to assume that his trunk was used only for purposes of wagging, while his tail was used for carrying things about, that his ears were not used for hearing, but for the absorption of food. It is doubtful whether I should be justified in deriving much comfort from the thought that this animal was an elephant.

I have frequently meditated upon what I have sometimes called the "irrelevance of the obvious." I picture a situation where I set a problem to a school boy. The problem is to the effect that a ball is thrown upwards with a certain speed, and I ask the boy to calculate how long it will take for the ball to attain a certain altitude. He comes back and complains that I have not given him enough information. I ask him what further information he desires. He tells me he would like to know the color of the ball. I tell him that the color does not matter. But he may not like that, because some of the reality of the ball has vanished from his vision with the color. He asks me for the weight of the ball, and I tell him that doesn't matter either; and I add to his troubles by telling him that I will withdraw even my remark that it was a ball and leave its shape indefinite. Then, if he is over-materialistically minded, he will explode entirely and demand to know how he is to work out any problem about the body if I won't tell him anything about it. There is nothing left for him to think about, and he may well claim that it is difficult for the human mind to think at all unless it has something to think about. Well, to please him, I tell him the body is red, weighs ten pounds and is really a nice round ball. Now he is happy. He takes his paper and pencil, draws the round ball, puts a 10 inside it, paints it red in his mind's eye, and works out the problem. When he brings me the result, I inquire at what point the redness of the ball came into his calculations. He looks through them and finds it didn't come in at all. The result would have been the same for a blue ball. Then I ask him where the 10 pounds came in. He looks again and finds he did not use it; or, if he did, it cancelled out, so that the result would have been the same for a fifty-pound ball. Finally, I ask him where the roundness came in, and he finds he did not use that at all. So I say to him, "Don't ask me a lot of unnecessary things again." But I think I hear you sympathizing with the poor student. "What harm," you say, "did the redness of the ball do? Why did he sin in thinking it was 10 pounds in weight and that it was round, if after all these things did not matter?" Well, I agree; in this particular case the redness did no harm. But I suspect that if I let the student think the ball is red, he will come to me some day with some ideas founded purely upon the redness of the ball. He will be

troubled because he will want some other ball to do the same sort of thing that this ball did and will be unable to satisfy himself because, perchance, the second ball is blue. Then, I shall have to go to the trouble of raking up past history to show that the redness did not matter in the former case; but, if he has enjoyed the vision of redness for a long time, his whole mental equilibrium may be destroyed if I take it away, and he may be quite unable to think at all without it.

An archdeacon has been defined as one who performs archdeaconal functions. Sometimes we laugh at that definition; but, provided that the functions are expressed explicitly, it is a very good definition—a much better definition, for example, than one which defines the individual in question as one who wears gaiters and a top hat of rather ostentatious shape. It is true that the gaiters and the top hat are the most immediately obvious features of the archdeacon, but one who riveted his attention on these appendages as the most fundamental attributes of an archdeacon might be at a loss to understand the significance of the individual, if for some reason he were without them, in spite of the fact that he might be just as good an archdeacon. The obvious part of the archdeacon is irrelevant to his true functions. And, so in science, we encounter many instances where we choose to think of things mainly in terms of their activities, and we are loth to add to them appendages which may hinder or complicate these activities.

Thus it appeared that all that was gained in any attempt to hang on to something like a model for the atom was to hang on to something which played no part in anything which really mattered, something which was cumbersome, a continual source of trouble and whose only use was to provide an illusion of comfort based upon some idea of reality which it might be supposed to afford.

In the next stage, which has developed during the last ten years, physicists have been content to make a complete break with the idea of models and to formulate the principles of atomic activities in purely formal terms. The rules which govern the behavior of the atoms are more like the rules of a game. We do not hope to see why they should be so. They, themselves, are the "why" of everything, and there is no "why" for them. The desire for a model was simply the unconscious desire to understand the unknown by analogy with the known. If we wish for an analogy to describe the modern view of the atom, it is not in terms of models that we must seek it. The characteristics of individuals would give, I think, a better analogue than those of machines.

In ancient times, when unaccountable things happened, people attributed them to the gods. If thunderbolts fell, the gods were angry. If all was fair, the gods were pleased. Of course it was necessary to come beforehand to some agreement as to the dispositions of the gods. Now in the modern theory of atomic structure, we may liken the atom to the gods. We have come to realize that the atom can exist in a number of different states of energy. We may liken these states to different states of the gods: the gods in peace, the gods at war, the gods hunting, and so forth. Now the mathematician has found out how to calculate, for the atom, a quantity analogous to what we may call the degree of amiability of disposition of the gods in these various states.

In any one of these states of the atom there is a quantity which we may call the degree of anger of the atom, and determined by the external conditions to which the atom is subjected. The atom has the characteristic of being angry in a lot of different ways at once. It is as though the gods had righteous anger, malicious anger, war-like anger, and so on. When the atom is angry, it may do one of the various acts which it is capable

of doing. It may emit a splash of energy associated with one kind of light or a splash associated with an x-ray or it may hurl out an electron. If, in general, the atom is angry in a lot of different ways at once, then the chance that it may do the various acts associated with the various kinds of anger is to be regarded as proportional to the intensity of the appropriate kind of anger. It will be observed that there is no certainty that the atom will do any one particular thing. There is merely a chance, a chance which is proportional to the kind of anger associated with the event. The atom is like a cat. You may torment it and it may do nothing, but the chance of getting scratched is proportional to the annoyance of the cat. There is no attempt to make a story of just how the atom operates when it "strikes." Indeed, the physicist has come to see that there is very much less content to that question than might be supposed.

But, you may say, is this not a terribly complicated way of talking about atomic phenomena? No, it is ultimately more simple. In other words, we can get a better correlation between the various actions of the atom by referring them to laws about what we may call the "temperament" of the atom than by seeking an explanation in terms of springs and weights. After all, that is not surprising. Who would attempt to decide what an operatic prima donna, or, for that matter, any woman, would do under given circumstances, by an appeal to the laws of springs, weights and machinery? The fundamental thing is that she is angry, for instance. That is the starting point, and there is no going back of that fact. Everything is accounted for in terms of the anger, but there may be no accounting for the anger.

The modern view of atomic structure which I have sketched very incompletely possesses an applicability and meaning over a much wider range of phenomena than was the case with the older theories. It is true that we do not *see* just how things should go in certain cases, but the underlying general principles seem to be there. The story of the atom's light emission, of the conduction of electricity in metals, of the photoelectric effect, of x-ray phenomena, of electric fields necessary to pull electrons out of metals under different conditions—all these become told in terms of a common language; and, while the story of the nucleus and of atom-building processes has not been completely told, a good beginning has been made.

One of the chief revolutions in thought brought about by the new philosophy in physics is the denial of the principle of determinism. If the positions and motions of the sun and planets were given at some instant, then, through the operation of the law of gravitation it is possible to calculate their positions and motions for all time. We can calculate what the solar system will look like a million years hence as easily as we can calculate what it will look like to-morrow. The future history of the heavenly bodies is irrevocably bound up with the present.

Now, altogether the laws which govern the more detailed activities of matter in general and of atoms in particular may be expected to be far more complicated than those which govern the solar system, there was always at the back of our minds the thought that if we knew what those laws were we could calculate, with absolute precision, the story of the future in terms of that of the past. Driven to its logical conclusion, this would mean that the act of my giving this address to-day is intimately bound up with and in a sense a direct consequence of what happened in the reign of Julius Caesar. In a sense, Julius Caesar, or some of his contemporaries, was subconsciously aware of the necessity of this address, and somehow or other managed through many generations to convey the idea to President Tigert. At first I am overwhelmed with the tremendous responsi-

bility placed upon me by Julius Caesar and his contemporaries in arranging, so far ahead, that I should speak to you today. But on second thought I cease to worry, for I realize that after all the responsibility is not mine and that really the address itself was, somehow or other, subconsciously written, or at any rate, determined, at the time of Caesar. The paradoxes in these matters have worried the man of science for many years. He hated the implications involved in such examples as that I have cited in connection with Julius Caesar and my address. If he did not admit them his whole scheme of physical law seemed to break down. And yet he was frightened from the opposite angle, when he thought of free will, so he went to church on Sundays and believed in free will, and during the remainder of the week he sought to show by his experiments and theories that everything was predetermined. While my own view as to this question of predetermination versus free will, etc., holds that it is rather a tempest in a teapot, and maintains that in the last analysis there is not as much difference between them as is usually supposed, the limited space of this address will not suffice to give the reasons for this attitude. The point which is to be emphasized here, however, is that we have come to realize in physics that an expression of the laws of nature in such a form that we say such and such a thing has only a certain chance of happening, rather than a certainty of happening, is not such an expression of incompleteness of knowledge as we formerly thought. We can have the laws in this form as a practical basis for unifying our experiments; and the old-time desire for something which seemed more "complete" is rather analogous to the desire of one who asks the question. "If an elephant could solve mathematical equations, would he also be a good musician?"

Many who have grown old in the mechanistic vision of nature view with regret any departure from it. They hope and hope that some day one will find once more a way to view the atom as mechanistic. I, for one, would be willing to join in the labor of striving continually for this goal but for one thing. That thing concerns the fundamentality of the goal itself. The more critically we examine the matter, the more do we find that there is really nothing in the mechanistic picture as a starting point which gives it a right to pose as a more fundamental starting point than any other. The mechanistic picture is pleasing to us because we are familiar with it, and this familiarity gives a certain illusion of fundamental contentment in it, as though we felt that once we could get back to a mechanism we would have arrived at an explanation which itself called for no explanation. There was a feeling that every other starting point was a makeshift, was artificial and called for a reason, but that the mechanistic starting point called for no prior reason. Now I have no quarrel with the idea that the mechanistic starting point calls for no prior reason. My quarrel is with the claim that it is unique in this matter. My quarrel is with the idea which forbids any other starting point to claim the same thing. I am aware that a superficial view of the mechanistic picture seems to give it a substantiality, a reality, superior to other pictures. Had I the time, however, I could take any one of these pictures which are especially appealing to you and if you should point out to me the things in it which gave it the semblance of fundamental reality, I could contrive to make you extremely uncomfortable in your reasons for contentment.

When one is confronted with a situation such as one meets in devising theories of the atom, one is apt to be worried continually by the groans of a specter which is always in attendance when anything new is under consideration. The specter's name is "Common Sense." He

is usually regarded as a most respectable being. He manages to preserve a high reputation for profundity by a dignified avoidance of saying exactly who or what he is. Now, I will not deny that "Common Sense" has his merits. In his proper domain he is a counselor of priceless value; and it is because he justly inspires such confidence in that domain that he becomes the most dangerous of deceivers of those who seek his guidance outside of it. For "Common Sense" seeks to pin all thoughts of the new to the fabric of the old, and so, ofttimes, he distorts the meaning of the new by destroying that form which was inherent in it in its own right, and for no purpose other than to fit it to a pattern with which it has no harmony. The result is a bizarre and shapeless thing out of harmony with the form into which it has been forced and out of harmony with the form which was its own. Common sense in natural philosophy repatterns itself from age to age. At each stage of its development it seeks to generalize the ideas born of the experience of the immediate past and to weld them into bonds which sometimes restrain the future. Thus, the breeders of error in the epoch to come are sometimes the truths of the days which have gone.

It was the common sense of the ancients which made them see the sun as carried around the earth by angels. It was the common sense of the Egyptians which made them see the universe as a box with a river running around the outer edge, the river carrying a boat and the boat carrying the sun. It was common sense which, in the time of Kepler, saw the sun endowed with spokes to which were attached the planets and which, through the rotation of the sun, drove the planets around in their orbits. It was the common sense of the astronomers of the time of Galileo which made his discovery of the satellites of Jupiter seem nonsense and his discovery of the laws of falling bodies contrary to reason.

And so common sense to-day groans at the modern atom. And yet in what a curious light it places itself by so groaning. For, to explain the actions of matter in bulk we have been driven to the thoughts of atoms and molecules. Then we have felt the necessity to go further and formulate a set of laws for these atoms which would account for the behavior expected of them. By a strange kink in the psychology of mankind, common sense has held us to a hope that those laws would partake of the same nature as those for matter in bulk. It is as though having studied cities, and having come to the discovery that they were composed of buildings, which in turn were composed of bricks, we had then begun to meditate upon the bricks and had sought to see some way in which they could be regarded as composed of houses put together in some kind of way suitable for the explanation of their tenacity and strength. Common sense is a good servant, but a bad master. So beware how you glory too much in good old "horse sense"; for, in the last analysis, "horse sense" is in all verity the kind of sense that a horse has.

Quite apart from the philosophical principles involved in the theory of the atom, the last two or three decades have brought to light a startling picture of the way things happen in the atomic world. One of the first things which surprises us in examining this picture is the fact that the atomic activities which constitute the chief phenomena of our interest are activities whose occurrence is so very rare from the point of view of the individual atom that they would constitute miracles to an intelligent inhabitant of an atom, if we could imagine such a being. In every cubic inch of the air which you breathe there are about ten thousand molecules which are in a peculiar state. They have lost an electron and are consequently charged to the extent of one proton. To us there is no miracle about this matter. I could bring

into this room a comparatively small piece of apparatus with which, in five minutes, I could measure the number of these peculiar molecules. Yet, think what a strange phenomenon we have here when viewed from the standpoint of the molecules themselves, for that cubic inch of air contains about five hundred million million million molecules, and only ten thousand of them have lost an electron. In other words, out of every fifty thousand million million molecules only one has lost an electron. If a molecule were to go about saying that it had once seen one of its brothers which had lost an electron, the story would be less likely to be believed than would the assertion by some person that he had seen a man with two heads, if he were the only person who had seen such a monstrosity during the whole history of the human race. Indeed, the assertion in question would have a much better chance of being believed than would the story told by the molecule which had lost an electron. For a molecule would, on the average, have to meet fifty thousand million million other molecules before finding one that had lost an electron; and if you could have lived long enough to have met all the people who have ever lived, in your search for the two-headed man, you would probably have met less than a million million people.

We may view the matter from another angle. The charged molecules in the air attract one another and so are continually coming together and neutralizing one another's charges. It is only because electrons are being continually torn from the molecules of the atmosphere that all the supply of charged molecules does not disappear. An important agency responsible for tearing the electrons from the molecules of the air is the cosmic radiation which comes to us, probably, from outside our atmosphere. In order to account for the maintenance of the observed number of charged molecules in a pure atmosphere it is necessary to suppose that in each cubic inch about twenty or thirty molecules have an electron torn from them each second; and, as a matter of fact, we know that the cosmic radiation is capable of accounting for such a result. But think what an exceedingly rare phenomenon this catastrophe of the loss of an electron is from the point of view of the molecules themselves. It is as rare a catastrophe to the molecules as would be a murder in the realm of mankind if, with the population of the earth at its present value, only one murder were committed on the whole earth in three hundred years.

Most of the outstanding phenomena of modern physics are miracles from the point of view of the atom. The photoelectric effect, which is responsible for the operation of the photoelectric cell, which in turn is responsible for the wireless transmission of pictures, is the ejection of an electron from an atom through the agency of light. We have been accustomed to think of an atom as a little solar system with electrons revolving around a central nucleus. Now in the photoelectric effect, you must think of a light beam shooting into an atom and hurling one of these electrons out of the atom in some such manner as that in which we might suppose a flash of light from the depths of interstellar space to burst into our solar system and hurl the earth into outer darkness. The latter idea is a fantastic one, you will say. True, but much less fantastic than the photoelectric effect would seem to an inhabitant of an atom if there were any inhabitants. For, even if we confine our attention to the atoms (they are atoms of potassium or caesium) which are on the sensitive surface of the photoelectric cell, we shall find about a hundred million million million of such atoms, and even with a strong photoelectric effect any one of these atoms would, on the average, suffer the catastrophe of the ejection of an electron only once in ten million

seconds, *i.e.*, about three times a year. But a year of our time would seem very long from the point of view of the atom. Things happen very rapidly on the atom. In the sense that the year for an electron of the atom is the time taken for that electron to revolve once around the nucleus, one of our years is equal to about thirty thousand million million million atomic years. Thus, from the point of view of the atom's measure of time, an atom of the sensitive surface of the photoelectric cell experiences the catastrophe of the photoelectric effect only three times in thirty thousand million million million years. Such a phenomenon may well be regarded as a miracle.

In an incandescent gas, we have been accustomed to think of the emission of the light as a phenomenon accompanying the fall of an electron from some orbit around the nucleus to another orbit of smaller size, a phenomenon analogous to the fall of an electron from some orbit to some other nearer the sun. Even in the case of a gas which is emitting light copiously, however, the number of atoms of the gas which participate in the light emission at any instant is so small that to the individual atom the phenomenon of light emission must seem as remarkable as the fall of Neptune from its orbit would seem to us. X-rays are produced by the bombardment of the atoms of a certain piece of metal in the x-ray tube by high-speed electrons. Yet even if we should confine our attention to the particular atoms which constitute that particular piece of metal which went into the construction of the x-ray tube, for the atoms, the phenomenon associated with the emission of an x-ray is such a rare one that if you lived on one of the atoms, participating in the pace of life natural to the atom, you would probably be put in an atomic madhouse if you insisted on suggesting that any such phenomenon as the emission of an x-ray had ever occurred.

With what a curious situation are we presented. Here is a set of phenomena which constitute the crucial activities upon which modern science is based. The evidence of these things is all about us—the phenomena themselves are less obscure to us than arguments about atoms and molecules. Even in the realms of nature's spontaneous activities they play a fundamental part. The emission of light goes on everywhere. The photoelectric effect is continually operative in the economy of plant life; and yet, from the point of view of the actual things which are the seat of these phenomena, from the point of view of the atoms, the phenomena themselves are of such rarity that no less drastic a word than "miracle" is fit to describe them. Imagine an inhabitant of an atom looking out upon the external world and seeing a furnace. The phenomenon should surprise him considerably; for he would be unable to explain its activities without invoking phenomena of such a character as would put him in a lunatic asylum if he suggested their possibility. And he would be in the same predicament with regard to most of the interesting things which were happening in the world. As a matter of fact, if he confined his attention to only the phenomena which he would have a reasonable right to expect, he would conclude this world to be a very uninteresting place.

I can well remember the time when of all "boners" which could be pulled by the student of physics in an examination, none was more heinous than one carrying an implication that atoms of matter could be broken up, or divided in any way into their constituent parts. To commit the sin of such an implication was for the poor wretch who was guilty to relegate himself to the realm of the scientifically hopelessly lost. Even the great Lord Kelvin shuddered when responsible men of science began to question the permanence of the atom. "For," said he,

"from the very word atom comes the implication of an indivisible entity."

Only one thought could be deeper in the mire of heresy than that which played in imagination with the permanence of the atoms, and that thought concerned the conversion of one element into another. The transmutation of the elements, the dream of the alchemists of old, was the typical example of wild charlatanism and uncontrolled speculation. To-day we face the accomplishment of this act heretofore regarded as so far outside the realms of possibility. One after another the elements are being broken up through acts under the control of man. They are being converted from one to the other; and, while we have not reached the goal in which atomic transmutation has been realized in such large amount as to have a significant bearing upon the production of elements on a commercial scale, an encouraging beginning has been made. Indeed, already new elements, such as radio sodium, having properties different from those of the elements which nature has given us, are being produced artificially in amounts sufficient to be of use in medical science.

Within the last few years, we have come to a realization that matter itself, formerly thought indestructible, can in actuality disappear, and that when it does so disappear, energy is created in its place. So great is the energy equivalent of even a small quantity of matter that the annihilation of a single drop of water would produce enough energy to supply two hundred horse power for a year. For many years the source of the heat poured out from the stars was one of the most perplexing mysteries of science. Were the story simply that of a hot body cooling, our sun would have run cold almost within historic times. None of the more obviously available sources of heat were adequate to the task required. Now we believe that in the annihilation of matter by the devouring of their own substance the stars find that source of energy to pay to the universe the tax which they must pay continuously in the form of radiation.

It is far beyond the scope of this address to enumerate all the fields of practical utility in which the scientific discoveries of the last thirty years have found place. It is a significant fact that most of the scientific developments which have played vital rôles in the practical affairs of life have arisen from discoveries made in the first instance with no utilitarian end in view. It is not meet, however, that one should seek to excuse the existence of any science or art by pointing out its utilitarian features.

In the matter of utilitarianism I have sometimes meditated upon a supposed conversation between an apostle of utilitarianism and one whom we will call an artist of the art-for-art's-sake type.

"Of what use are those pictures in the Vatican?" asks the utilitarianist. "They do nobody any good and only wasted the time of Michelangelo, who painted them."

"And what kind of creative work would you regard as of use?" asks the artist.

"An example is the development of the steam engine and the automobile," says the utilitarianist.

"But why are these of use?" says the artist.

"Because they enable one to move about faster and get more done," says the utilitarianist.

"But why move about faster and get more done?" replies the artist.

"Because by doing so you create wealth for yourself and others; you save time and are enabled to enjoy more leisure," is the rejoinder.

"And what is the use of money and leisure?" asks the artist. "Is it not rather boresome to have nothing to do?"

"Oh! it is not necessary to do nothing," is the reply. "You can travel and enlarge your mind."

"But," says the artist, "what is the

good of traveling? You only get seasick and very tired."

"Oh!" replies the utilitarianist, "it is a wonderful experience to travel. You can go to the old world and visit all those places of classic renown: Paris, Venice, London."

"But," says the artist, "is that not very disturbing? I hear that many of these places are unsanitary. The food is not what you are accustomed to, and sometimes the people are not overfriendly."

"Those are but small matters," says the utilitarianist. "They are far outweighed by all of the other riches you fall heir to. You can bask in the exhilarating sun of the Alps. You can drink in the beauties of the Mediterranean. You can visit ancient Rome; and when you are there do not fail to see those marvelous pictures painted by Michelangelo in the Vatican."

And so I have wondered if we should be far from the truth if we should maintain the thesis that the only ultimate excuse for the existence of the things utilitarian is that they provide the means whereby we may enjoy the things nonutilitarian.

In the new era which is before us, and upon which you will now enter, mankind is likely to enjoy far more leisure than has been the lot of our forefathers. With the world's work done largely by machines, the day is coming when but a fraction of man's time will be occupied by the necessities of existence. What are we going to do with the remainder? I think it is safe to say that one obtains permanent satisfaction only out of the things on which he has done serious work. You may decide to devote the whole of your life to golf, but unless at some time in your life you work as hard as a navvy to improve yourself in the game, you will soon reach a stage where your enjoyment lags. I would suggest that the very characteristic which determines a good game is that it shall be something at which one can work continually, in which one can continually improve and yet never attain perfection. Following this criterion, golf is a good game. Billiards is a good game. Ping pong is not such a good game, because in a relatively short time a large number of people can go practically as far as it is possible to go in the game, and it has no further richness to stimulate improvement.

The consciousness of improvement is more satisfying than the realization of success. There is no more unhappy being than the man or woman who has attained middle age and has never done any serious work at anything. Such people go to concerts, but know nothing about music, and soon they are sick of concerts. They go to plays, knowing nothing of literature, and they are sick of the theater. By the time they are forty they have exhausted all the superficialities of pleasure and are heartily sick of everything. The only excitement left is an ailment or a grievance. In the years which have passed, this state of affairs has been the potential lot of the wealthy few, and only they have had the problem of leisure before them. In the years ahead of us, however, the leisure problem will be one for all of us. It will be necessary for an individual to work hard in his youth that he may play with satisfaction in his maturity. I vision a day when each of us will have his vocation, and an avocation in which he is not necessarily less proficient than in his vocation. The former is his contribution to the necessities of existence; it is the thing he is paid for. The latter he does as his own master. When this day comes perhaps we shall once more find a world in which there is time to do a thing well.

In this world of turmoil and scientific achievement, where the science of even fifty years ago seems obsolete and primitive in its character, compared with the

science of to-day, it is almost a shock to turn to other fields where time has wrought less changes. Three hundred years ago, the old Italian masters made violins, violoncellos and similar instruments. The general form and character of those instruments is quite obvious, and indeed for five dollars one can buy a violin which looks in its general characteristics very much like a "Strad." But the "Strad" is worth fifty thousand or even a hundred thousand dollars; and there are many musicians who will tell you that it is worth it, and that the value is not a fictitious one based upon the antiquity and rarity of the instrument. Those old instruments are not merely show pieces. They are not like the ancient museum parchments kept sealed in light-protected cases, and exhibited on occasions only for a moment. They are live things, working hard every day in the hands of the great violinists and 'cellists of our time. They stand as the product of a skill in craftsmanship which grew in an atmosphere sympathetic to it. There was in the air of sixteenth and seventeenth century Italy the spirit of the making of these instruments so that despite the meager knowledge of the principles of acoustics, despite the primitiveness of the tools and despite the ignorance of the chemistry of the varnishes, a result was achieved which, even to-day, transcends the efforts of modern skill. Machines can make many things better than the hand of man; but there are some things born of the hand of man and of the heart which no lifeless thing can duplicate. The spirit which guided the master violin-makers of old could hardly thrive in the civilization which has seen the rapid growth of the machine age. The painters could not live, and indeed would not be content to live in this age with the return with what they wish to paint might bring them. They would have to paint advertisements, and portraits of uninteresting people who paid them well for it.

If and when the day comes in which, through a greater leisure, these great arts and other non-utilitarian activities can claim once more an adequate proportion of the time and sympathy of mankind, then perhaps we may regain some of the things which mankind seems to have lost. It is for a new generation such as you represent that this millennium awaits. When it comes, see that you use it well.

NOTE: Acknowledgment is here made of the courtesy of the Macmillan Company in permitting the inclusion on pages 433, 437, 438 and 441 of certain quotations from the speaker's book, "The Architecture of the Universe," Macmillan, 1934.

THE ORIGIN OF CONTINENTS AND OCEANS

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AMONG the very interesting and puzzling problems in the field of geology and geophysics is that of the origin of continents and oceans. If we could solve this one, it is probable that much light would be thrown on many other geological problems.

There have been many hypotheses regarding the origin of oceans and continents, but most of them seem to conflict with the laws of physics and mechanics and therefore seem to be untenable. The only hypothesis that seems to be a reasonable one, and this has some difficulties, was advanced many years ago by Sir George Howard Darwin, son of the naturalist, Charles Darwin. He advanced the idea, and seems to have demonstrated it to the satisfaction of astronomers who have succeeded him, that the moon is gradually increasing its distance from the earth because of tidal friction. He worked backwards and found that at some time in the past, not so very long ago, astronomically speaking, the moon was exceedingly close to the earth. This led him to the opinion that the moon probably was formed of material that had been thrown off from the earth as a result of tidal forces. It would naturally be the surface material that would be thrown off. It is interesting to note that the mean density of the moon is about that of the denser terrestrial rocks, allowance being made for increase in density with depth under the pressure of lunar gravity.

The moon seems to be somewhat different from the other satellites of our solar system. Generally these satellites are small in comparison with their primary planets, sometimes very small, but the moon is fairly comparable in size to the earth, its radius being about one quarter of the earth's radius. Conceivably, the moon might have been formed as an independent planet and later have been captured by the earth's gravitational attraction, but the idea that the earth and moon were once parts of a single mass is an attractive speculation.

In any body like the earth there is bound to be a tidal rise and fall of its surface as it rotates relatively to another body that lies within a reasonable distance of it. This is true, even though the material composing the rotating body is solid and should have the rigidity of steel. For the earth there would be tides of its solid matter as well as tides in its oceans.

All tides on the earth are caused by the differential attraction of the sun and moon on different portions of the earth. When the sun and moon are in conjunction or in opposition the tide-producing forces are at a maximum. Halfway between these tides we have the minimum tide-producing forces, which give us the low or neap tides.

Since the earth was first formed, no matter how, tides must have been produced by the sun as the earth rotated on its axis. The high tides would occur at intervals equal to half the time required for the rotation of the earth relatively to the sun.

Each body, such as the earth, has what might be called a natural period of oscillation or vibration. If the earth were acted on by suddenly applied forces and a vibration resulted, the period of vibration would be that which is normal to this great mass. Darwin postulated that the period of the rotation was at first very rapid and finally decreased as the

result of tidal friction till the tidal interval approximated very closely to the period of the free vibration of the earth. As the two approached complete accord the tides must have become greater and greater. As the bulge on the earth caused by the tide-producing forces of the sun increased, the earth became unstable and, according to Darwin, a disruption occurred. If this actually happened, probably the tidal bulge on the side of the earth towards the sun was more attenuated than the opposite bulge, so that at the time of greatest instability only one mass would have been detached from the earth. After this disruption had occurred the period of the tides and the period of the free oscillation of the earth differed by such an amount that the tides again became normal.

One frequently notes the effect of a repeated and periodic application of a force to a body which can oscillate, and how a slight force often repeated increases the vibrations or oscillations of the mass. If one takes a tub of water and lifts one edge a small fraction of an inch and repeats the lifting at such intervals as to synchronize with the oscillation of the water in the tub, these oscillations are made very large. In fact, they become large enough to cause the water to spill over the edge of the tub, unless the water is very shallow in comparison with the depth of the tub. Again one frequently notes the vibrations of a suspension foot-bridge when a number of people walk in step across the structure. In fact, a body of troops marching across a suspension bridge is ordered to break step in order to prevent violent vibrations.

Darwin did not cover the question of oceans and continents in his discussion of the possible formation of the moon by tidal effects, but, shortly after he proposed his theory, the Reverend Osmund Fisher, a British geophysicist, advanced the theory that the moon could have been formed from the earth in the manner postulated by Darwin, even though a solid shell or crust had been formed. He reached the conclusion that if the moon had been formed by a disruption of the earth after the crust had appeared, the disruption would have left blocks of the crust to form continents and islands, and that the area from which the material was detached to form the moon would be depressed because of the absence of the light crustal material.

This idea of Fisher's has been discussed by subsequent writers. Some have raised objections to the hypothesis, while others have strongly supported it. It seems to me that what we should do in attempting to explain any natural phenomena is to analyze each hypothesis that has been advanced and to hold to the one that apparently has the greatest strength. In my judgment this hypothesis of Fisher's, based upon the ideas of Darwin, meets this criterion.

We know from gravity data that the earth's crust is at least in an approximate state of equilibrium. It has been found that the probable depth to which the crustal material extends below sea level is sixty miles. This depth may be anywhere between forty and eighty miles, but in any event the earth's crust is like a huge blanket wrapped around the central part of the earth. This blanket is composed of material having residual rigidity. It will break if forces acting upon it exceed the limiting strength of the material. On the other hand, the material that lies below the crust has no residual rigidity to even comparatively small forces acting through geological times measured in hundreds, thousands or some greater number of years. This crustal blanket exerts approximately the same pressure on equal areas of the surface of the nucleus of the earth. It is similar to a great ice sheet on a lake or on the Arctic Ocean. The blanket stands high in some places, as continents and islands, because the material forming the crust below those elevated areas is less

dense than the average. The oceans are depressed because the material composing the crust beneath them is denser than normal.

This condition of equilibrium of the earth's crust is called isostasy. Isostasy is not a force; it is merely a condition that is approached by the crustal matter acting under the force of gravity.

The mineralogists have contributed to our knowledge of the densities of crustal material. They find that the igneous rocks of islands in the oceans have the heavier elements present in larger percentages than are found in the igneous rocks of the continents and of the large islands such as New Zealand and Australia. Then, again, the seismologists have furnished data regarding the densities of crustal material. They do not measure the differences in density of crustal matter, but they do find that the rate of transmission of the earthquake waves is faster under the oceans than under the continents. Presumably the crustal material under the oceans, being the more elastic, is denser.

Geologists have speculated for many years as to why the continents and oceans should continue to exist. Now that the geodesists, mineralogists and seismologists have learned that the material under the continents is lighter than that under the oceans the problem is solved. But there remains the problem of discovering how these differences could have occurred.

We have several theories regarding the origin of the earth. It is not possible to discuss those theories in this short paper. We may mention, however, that there are two that have many adherents: One, that the earth was pulled away from the sun by the attractive forces of a star passing close to the sun, or perhaps knocked off by an actual collision; and the other, the so-called planetesimal hypothesis. According to the first, the earth was a molten mass that gradually cooled and solidified. According to the planetesimal hypothesis the earth never was molten. It was formed by small masses collected together by their mutual attraction. We do know that the earth's interior must be hotter than at the surface. This is indicated by volcanoes, hot springs, outpourings of lava sheets and by the temperatures of wells and mines. The increase of temperature with depth varies for different places on the earth's surface, but a fair average is an increase of fifty degrees centigrade for the first mile. If that change per mile should remain constant with depth, the temperature twenty-five miles below the surface would be 1250° C, which is great enough to fuse rocks at the earth's surface.

No one can tell what the temperature of the interior of the earth was before the disruption of crustal material took place, but it seems to me to be reasonably certain that the temperature must have been very high and that the subcrustal material was more plastic than it now is. Observations for earth tides made by Michelsen and Gale showed that the earth as a whole is as rigid as steel. Is it not possible, if the rigidity of the earth were as great as that some billions of years ago, that the tide-producing forces of the sun would have been insufficient to distort the earth's form to the extent of making it unstable? Even if the disruption had occurred with a very rigid earth, however, there would be no difficulty in having the scars left by the removal of the crust healed by the upward movement of subcrustal material. The gravitational forces would have been so great that upon the removal of portions of the crust the subcrustal matter would be forced upward to fill the spaces. Since the subcrustal matter would be denser than the crustal mass removed, the new surface of the earth would be lowered over those areas where the crust had been torn away. If the subcrustal material had been very plastic or almost fluid, then the tide-producing forces

would have been more effective in distorting the former shape of the earth. Even though the earth may have been solid there would undoubtedly have been a breaking up of crustal matter, just as would no doubt occur to-day, because the surface of the ovoidal earth just before disruption would have been many million square miles greater than for the spheroid. We really have no definite evidence in favor of either a very solid earth or a very plastic or liquid one.

In any event, there is no explanation that has ever been advanced regarding the distribution of crustal material as we have it that is not subject to adverse criticism except this hypothesis of Fisher. No one can say that Fisher's hypothesis is true, but it is logical and in any event it does no violence to isostasy, or the equilibrium of the earth's crust. It is impossible on a molten earth gradually cooling to have the light material, which must have been present around the whole earth, pushed together into great masses to form continents. There is no force available inside or outside the earth which could have caused such a segregation of surface matter; nor on the planetesimal hypothesis can we imagine the granites, composing at least the outer portion of the crustal matter beneath continents, collecting in isolated masses. There apparently is a complete absence of granitic material under the oceans, and therefore it would seem to be logical to conclude that when the earth's crust was formed, a layer of granite covered the whole earth and that by some process it was disrupted, and parts of it went off into space. Whether the moon was formed this way or not makes no difference, but apparently there must have been a disruption or we could not have the present distribution of crustal material.

It has been estimated that if the hypothesis of Darwin is true, the earth would have to be distorted into the form of an ovoid with its major axis approximately twice as long as its minor axis before the disruption of a portion of the mass could occur. If the earth were to assume the ovoidal shape, with its major axis twice the length of the minor one, the surface of the ovoid would be approximately fifteen million square miles greater than the surface of the spheroidal earth. This would mean that there were many spaces on the earth's surface before the disruption from which the granite blanket was absent. Those spaces would be filled almost as soon as formed by the upward movement of the subcrustal material under gravitational forces. Those spaces would not be closed again as the major axis changed its position in the earth's mass, but there would be a movement up and down of portions of the earth as the tidal bulge moved around its mass in response to the tidal forces. It is rather interesting to note that the two coasts of the Atlantic are so nearly alike that they have the appearance of the shores of a great river. Is it not possible that North and South America could have been torn away from the crustal material that forms Europe and Africa just before the disruption occurred?

I can imagine, if the oceans and continents were created in the way that we are discussing, that there would be many small fragments of the original crustal material left behind. We have islands in all the oceans and also ridges and plateaus that do not reach the surface of the water. It is possible that these elevated portions of the crust under the ocean represent the presence of some of the original crustal material.

Some other hypothesis may be advanced to account for oceans and continents, but the one which we may label the Darwin-Fisher hypothesis certainly is the most probable one that has been advanced up to the present time. The question may be asked, "When did all this occur?" The answer must be, "A long time ago." According to the best

geological evidence the present sedimentary age of the earth began about one billion six hundred million years ago. It is reasonably certain that the continents and ocean basins were formed prior to that time, for without erosion there could be no sediments. In order to have sediments we must have running water. Running water carries material from high areas to low ones. If the original crust of the earth had been uniform in elevation with only local humps and hollows, the waters that were on the earth would have stood at about the same depth over the whole surface. Then, no matter how much rain there might have been, in the absence of exposed land there could not have been any erosion. It would seem from this that there must have been an irregular surface of the earth at the beginning of sedimentation.

Erosion and sedimentation are really very important factors in the changes that occur on the earth's surface. We have a number of facts that are quite valuable as the basis for geological and geophysical investigations and speculations. We know the shape and size of the earth with a very close approach to accuracy. We know the mass of the earth, the densities of its surface rocks and the approximate age at which sedimentation began. We know that we now have rainfall at the rate of approximately thirty inches per year over the land surface of the earth. It is many times that in some areas and in others there is scarcely any rain at all. By using an average of thirty inches we would have at that rate approximately one mile of rain in two thousand years. But since the sedimentary age is eight hundred thousand times that much, we can see that if the rate of rainfall has been uniform there could have been eight hundred thousand miles of rain.

The rain falling to the earth carries to the ocean waters vast quantities of material in suspension and solution. According to the results of the analyses of river waters by scientists of the U. S. Geological Survey, the mass of material that goes to tide water in nine thousand years from the United States alone is equivalent to a blanket one foot in thickness over this country. This rate of erosion is small in terms of the length of human life, but in geological times the amount of erosion that could have occurred is enormous. One mile of erosion would have occurred in forty-five millions of years, if the configuration of the surface of the United States could have been maintained as it now is. But this is only about one thirty-fifth of the total time during which there has been rainfall, erosion and sedimentation. Great piles of sediments are accumulated at the mouths of rivers, in inland seas and lakes and along our shores. These accumulations certainly affect the isostatic equilibrium of the earth's crust. The crustal material will sag under the added load. Then again the areas from which the sediments are derived become lighter and, therefore, there is a tendency for them to rise by the intrusion into crustal space of subcrustal material. The balance is maintained to a rather high degree of perfection. This is indicated by gravity and other geodetic data that have been accumulated over many parts of the earth's surface.

Geologists tell us, and I believe there is no opposition to this idea, that all mountains and plateaus occupy areas that were once below sea level and were receiving large quantities of sedimentary matter. There must, therefore, be a relation between sediments and the formation of mountains and plateaus. Is it not possible that erosion and sedimentation are the principal factors in the changing elevations of the earth's surface?

If the temperature increases with depth, then, as the crustal material is

pushed down by the weight of the sediments, the matter would occupy spaces that are hotter than those previously occupied. Perhaps the eventual rising of the isogeotherms would cause an expansion of the crustal matter and perhaps a change of physical state, thus creating a plateau or mountain range.

Areas that were once occupied by mountains and plateaus are now below sea level. Here we have the opposite process. As the crustal material rises, as erosion lightens the crust, matter is brought into higher and colder regions and eventually as it cools to the normal temperature of its new position, the matter then contracts and forms a depression or trough into which new sediments will be deposited. There is evidence that mountain areas have gone up and down more than once, and it is possible that the explanation may be found in the effect on the equilibrium of the crust of the unloading and loading resulting from erosion and sedimentation.

We must acknowledge that we are still in the speculative stage regarding the cause of the existence of ocean basins and continental masses. Yet speculation is very fruitful in scientific research. Without speculation we become merely observers of phenomena or collectors of data. The hypotheses enable us to make tests and to observe and collect with a greater degree of effectiveness. It is possible that in the future more light may be thrown on this very interesting and important geological phenomenon of oceans and continents. The Darwin-Fisher hypothesis may be substantiated or the evidence may be so strong against it that it will have to be abandoned.

ON THE EXISTENCE OF FERROMAGNETISM

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I WISH to revive a question, not to answer one. Why does ferromagnetism exist? The question was probably first asked by that early shepherd who, as we are told, discovered the phenomenon for the Greek philosophers, and I want to suggest that it is still, in a certain sense, an unanswered question.

It has been answered at various times in languages that would not satisfy the modern demand of an explanation—that it correlate phenomena. And in the times of the recent classical physics, probably the nearest thing to an answer was proposed by Weiss, who, as you know, assumed that the elementary magnets, whatever they be, have their rotations dictated not only by the usual statistical forces of temperature perturbation and the comparatively weak influence of a magnetic field (these effects alone constitute a theory of paramagnetism) but also by a strong orienting force of unknown nature but in strength proportional to the magnetization and tending to align the elementary magnets along the direction of magnetization. In other words, he simply assumed that the elementary magnets are coupled together in such a way that, if several of them point in the same direction, they conspire to make many others point with them. It is apparent that such a mutual orienting force, if strong, could amplify the feeble efforts of an external magnetic field in turning the elementary magnets parallel to one another, and thus give rise to the existence of ferromagnetism. It is equally apparent that such a mutual orienting force does not have as a consequence either hysteresis or ordinary remanence, for it only tends to hold the elementary magnets parallel to one another, not parallel to any particular

direction in the metal. These technically vital phenomena, dependent upon preferred directions of magnetization, we shall lay aside as not essential to the theory of the existence of ferromagnetism.

This ad hoc assumption of Weiss is so successful in correlating the maximum intensities of magnetization at various temperatures, for example, that we might accept it as an answer to our question. But to the curious mind the assumption merely challenges with the question anew: Why do the elementary magnets have a strong tendency to point parallel to one another (and, incidentally, what are the elementary magnets)?

Because of the crystalline nature of metals, we feel sure that no bit of matter larger than an atom is free to rotate within a metal. So we conclude that the elementary magnet is an atom or a part thereof. This being the case, it can easily be estimated, by using the measured magnetic properties of the individual atoms and the known density of atoms in the metal, that the *magnetic* force between the neighboring atoms (or any parts of atoms) is about a thousand times too weak to explain why ferromagnetism should exist at ordinary temperatures.

The question, "What are the elementary magnets?" can be answered quite definitely by a nice combination of theory and experiment. The theory of atomic spectra, together with experimental information on that subject, tells us that there are two types of rotation in an atom—two types of angular momentum—one due to the to-and-fro motion of electrons in the atoms, and the other type due to the fact that each electron is spinning like a top. Spectra tell us, further, that a certain amount of the spinning momentum carries with it just twice as strong a little magnet as does the same amount of angular momentum due to to-and-fro motion. When we magnetize a bar to a certain strength, the amount of angular momentum that we must twist into the direction of the axis during the process depends on whether we are turning little magnets due to electron spin or due to to-and-fro motion or both. We know from experience with gyroscopes that, when we try to twist an angular momentum in one direction, it produces a twist in quite another direction. So it is that, when we apply a magnetic field to twist the elementary magnets in a bar, the little magnets are first rotated sideways, but some other forces within the crystal act like friction in the bearings of a gyroscope, and the whole bar receives the twist, while the elementary magnets rotate into the direction of the field. By measuring very delicately how much the bar is twisted, it is possible to determine whether the amount of angular momentum is that of the spin or that of the to-and-fro motion, and experiments of Barnett show that it is the spin. So the electron spin is the elementary magnet.

The theory of atoms and the principles of gyroscopes have helped, and the theory of molecules also helps our query. We think of bringing two atoms slowly together. Each consists of a single electron gyrating to and fro about a nucleus. Each atom has as much positive as negative electricity, so they don't attract each other when apart. When they get near enough to one another that the two regions through which the electrons gyrate begin to overlap, then the electrons affect one another's motions according to the strange rules of a very important game (Pauli wrote the rule-book of this game, which is one of the laws of nature—it explains many things). When the electrons are spinning in the same direction, they try to stay apart and shun the space in which the two regions overlap! (When, contrariwise, they spin in the opposite directions, they tend to congregate!) If that

space in which the regions overlap is far away from the two positive nuclei, then the most important effect of the aloofness of the two electrons (spinning alike) is that they tend to inhabit regions into which they would have tried to push each other (because of their like charges) anyway, so their average energy is reduced because of their aloofness. The two electrons will then spin in the same direction in order to attain low average energy. (There is an opposite tendency when the nuclei are so close together and so close to the space in which the regions overlap that they make it a place of very low energy for the electrons.) This tendency of the electrons to spin in the same direction (and point their magnets in the same direction) is caused, we see, by electric forces, not by magnetic forces, and the electric forces are much the stronger. In fact, it can be calculated that, in a simple molecule like this, the tendency of the two electrons' spins to point the same way is strong enough that, *if* it should also exist between many electrons inside of a metal bar, it could be the cause of ferromagnetism, and the answer to our query. This important suggestion is due to Heisenberg. That "*if*" is the unanswered part of the problem. It seems quite possible that the tendency might not exist when an electron has neighbors on all sides, because if an electron in a metal tries to avoid one neighbor, it might merely back up into another, a thing that would not happen in the simple molecule. There are other reasons why the tendency toward similar spins might not exist in a metal. One of them involves the wave mechanics of the molecular problem a little more explicitly, so we shall here make a short wave-mechanical digression, repeating in another language some of the things we have just discussed.

When the two atoms of a molecule are separated, each has energy E_0 and its electronic behavior (and spin orientation) is dictated by the function ψ_α^a which satisfies the simple wave equation

$$(\Delta^a + V_\alpha^a - E_0)\psi_\alpha^a = 0.$$

Here α denotes which nucleus, and a, which electron, we are describing. The wave equation of the two atoms as they begin to approach one another contains an energy E which we suppose to differ by only a small amount (ϵ) from the total energy $2E_0$ of the two atoms far apart, $E = 2E_0 + \epsilon$. There also appear potential energy terms $V_{\alpha\beta}$, V_α^b, and V^{ab} representing interactions between nuclei, between nuclei and electrons, and between electrons, respectively:

$$(\Delta^a + \Delta^b + V_{\alpha\beta} + V_\alpha^a + V_\beta^b + V_\alpha^b + V_\beta + V^{ab} - 2E_0 - \epsilon)(\psi_\alpha^a \psi_\beta^b - \psi_\beta^a \psi_\alpha^b) = 0.$$

The last factor, an anti-symmetric combination of products of the single-electron functions ψ_α^a, is in that simple form an approximate solution of the equation for the case in which we are most interested, with the two electrons spinning in the same way. If, in this case, we multiply the equation by the simple product $\Psi_\alpha^a \Psi_\beta$ and integrate over the coordinates v, using the simple single-atom wave equation which states that some of the terms add to zero, we obtain directly the expression:

$$\int \Psi_\alpha^a \psi_\beta^b (V_{\alpha\beta} + V^{ab} + V_\alpha^b + V_\beta^a)\, \psi_\alpha^a \psi_\beta^b \, dv$$

$$- \int \Psi_\alpha^a \Psi_\beta^b (V_{\alpha\beta} + V^{ab} + V_\alpha^a + V_\beta^b)\, \psi_\beta^a \psi_\alpha^b \, dv$$

$$= \epsilon \int \Psi_\alpha^a \Psi_\beta^b (\psi_\alpha^a \psi_\beta^b - \psi_\beta^a \psi_\alpha^b)\, dv$$

$$= \epsilon (1 - S^2)$$

where $S = \int \psi_\alpha^a \psi_\beta^a \, dv^a$. In the last step we have used the "normalization" of the wave functions, and the term S enters because of the fact that the wave functions of the two atoms overlap in a simple way. The interpretation of this equation is important. The first integral is the ordinary average of the ordinary potential which is introduced into the problem when the atoms approach one another.

The second integral, starting with the negative sign, is known as the "exchange integral," and comes into the problem just because the Pauli rule states, in this kind of calculation, that we must use anti-symmetric solutions of the wave equation, made by interchanging the coordinates of the electrons. If it is positive, it helps to lower the energy of this state of two like spins. It is a quantitative measure of the effect that we ascribed above to the aloofness of similarly-spinning electrons. But, in order that the left member may be interpreted simply as an energy ϵ, the term S^2 on the right must be zero, which is not the case. We see that this term S^2 likewise entered the problem because of the possibility of interchanging the coordinates of the two electrons. In this simple atomic type of problem it usually leads to only a small correction.

But, in the similar but more complicated problem of the behavior of electrons in atoms in a metallic crystal, very many such terms S^2 enter the problem, in fact, as many as there are pairs of neighboring electrons to be interchanged! This is, for even a small crystal, a tremendous number of terms—about N, the number of atoms in the crystal. But worse than this, there are about N^2 terms S^4, and so on. Even if S were only a hundredth or so, such a great number of terms, in place of the single term S^2 above, would be expected to make a great difference in the result of our calculation. Yet this tremendous number of terms have been simply neglected in the best calculations which have yet been made to explain theoretically the strong coupling between the electrons in a ferromagnetic metal.

The accuracy of the calculation thus seems to depend in an ugly manner on the size of the crystal. Physically, the region in which spontaneous magnetization exists is probably rather small, due either to "mosaic" structure or to demagnetizing fields, so the number of atoms in our problem need be only a million or so. But even so, the amount of overlapping, which determines S, would have to be extremely small if the calculation for the crystal is to mean anything, and this would make the exchange integral and the coupling between the spins very small indeed. In this negligent approximation of Heisenberg, the theory could only be applied to very distended crystals, and would predict ferromagnetism for them only for temperatures within a few degrees of the absolute zero (which is hardly what we mean by ferromagnetism!).

Still we might use the theory to placate our curiosity, being content with a weak ferromagnetism of a distended crystal, if it were not for the fact that, as the crystal contracts, another strong tendency comes into play to oppose ferromagnetism. It is the rule forcing electrons of overlapping atoms not to move with the least possible momentum, but to acquire a considerable amount of kinetic energy, and more if their spins are similar than otherwise. (When the electrons wander through the same region, the Pauli rule states that the electrons with like spins must stay apart on a momentum scale, so to speak, rather than apart in distance.)

Because of the difficulty of making an adequate theory of ferromagnetism, perhaps it is worth while to examine some of the consequences of this very deficient type of calculation. We have already seen that there is a tendency toward like spins for the two electrons of a simple molecule only when their regions overlap in a space midway between the two nuclei and not near either nucleus. For this to be so, it is necessary that the region of an electron of one atom does not extend far beyond the midway point. The region of an electron must, then, be comparatively small, and, for ordinary crystal dimensions, it must be smaller than

the region of an outside electron of any atom. So it would seem that we should blame ferromagnetism on some of the inner electrons of the atoms, the regions of which are smaller. But the inner electrons of atoms are ordinarily so arranged, because of the Pauli rule again, that their spins stay opposite in pairs and just cancel out the magnetic effects of one another. From spectra it is well known that this is not always true, exceptions being found in that part of the periodic table around vanadium, iron, and nickel. Here we seem to have a rough indication of why ferromagnetism does not appear in all metals. It is also noteworthy that the regions of these "exposed" inner electrons are more compact for iron, nickel, and cobalt than for other elements (an idea due to Slater).

Finally, let us consider the possibilities of calculating this effect from a new and less erroneous point of view. Considerable advance has recently been made in the theory of cohesion of metals (by Wigner and Seitz and by Slater) by finding with rather tedious numerical methods a set of approximate functions to describe the motions of an electron through a crystal, with various possible momenta, and allowing for the fact that the peripatetic electrons still have some connection with the atoms. These functions are reckoned by considering only one sample region of the crystal, approximately spherical, belonging to one atom, since the function practically repeats itself in other regions. Each of these functions describing a possible motion tells a possible energy of an electron, and the possible energies come in clusters. The cluster or band of energies arising from the outside electrons of the atoms is quite broad, and there are, in simple metals, half as many electrons as possible kinds of motion, so each electron has (for the lowest total energy compatible with the Pauli rule) one of the kinds of motion and one of the energies in the lower half of the band. Besides reckoning these functions and energies, we must find out how much difference in the energy the "aloofness" of the electrons makes. This is not so very difficult for the outside electrons of sodium atoms in a crystal, because outside electrons have not very much momentum and therefore have long "wave-length," which makes their density throughout most of the region fairly uniform. This effect has been included in calculating the cohesion of sodium, for example.

For the inside electrons, a similar but probably narrower band of translational energies exists, and the energies should be calculable in just the same way. However, these inner electrons, being nearer the nucleus, have more momentum and shorter wave-length and considerably less uniform density, which makes the calculation of the "exchange" or "aloofness" effect more difficult than in the cases for which it has been carried out. The method is particularly well adapted to calculate only the increase of translational energy accompanying similarity of spins, which would have to be exceeded by the decrease of energy due to the greater average distance between the aloof electrons, a quantity more difficult to reckon. But we may hope that this new method will lead to a much more satisfactory answer than we yet have to our query, "Why is ferromagnetism?"

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE SCIENCE OF STUDYING HUMAN BEINGS

By Dr. HARVEY N. DAVIS
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SOME years ago an engineer of my acquaintance dined one night with the head of a considerable industrial establishment. In the course of the conversation the manager happened to mention with some pride an improvement he had recently made in the specifications on which they were buying one of the raw materials needed in their manufacturing operation. Instead of registering the polite appreciation that the occasion demanded, my friend blurted out: "Why do you waste your time over that sort of thing? For years you have been fussing over your raw material specifications that were already good enough. At the same time, you've been spending more each year on labor than on all your raw materials put together and spending it as blindly as if human beings were neat little packages of some thoroughly standardized product that needed no investigation beyond looking at the label. Why don't you put just a little of the same sort of engineering brains into buying your labor that you have put for years into buying your iron and copper and rubber and silk?" The industrialist looked at the engineer awhile, and then said, "All right, I'll call your bluff; you're hired; report at the plant next Monday, and we'll see what you can do." Out of that conversation grew the work that I am going to talk about this afternoon; out of it also grew a set of work samples and an employment office technique that a few years later attained and maintained for three years in that plant a labor turnover record of only 6 per cent. per annum under conditions where from 30 to 60 per cent. would have been not unexpected. And this is but one example of many that could be drawn from modern industrial psychology to show that there is beginning to arise in the world a real science of studying human beings.

One difficulty is basic in this field. It is that no two human beings are alike. Any laboratory can procure for study a sample of practically chemically pure copper, and this sample will be almost exactly like those that other laboratories have studied previously; this is what has made it possible to determine what we call "the properties of copper." But no laboratory can find a human being exactly like the one that another laboratory studied last week; this is what makes it impossible to talk about "the properties of human beings" or "the laws of human nature" in any but the vaguest of senses. Nevertheless, a scientific approach to the problem does seem to be possible, and the basis of it is twofold.

In the first place, the use of the statistical method makes measurement in the scientific sense possible to a surprising extent. If we try to compare one individual with another we get nowhere, because of unpredictable individual differences. But if we compare one considerable group of individuals with another and talk averages or medians or midmeans, we get measurements that are definitely reproducible from one group to another, and from one laboratory to another. And it is only when measure-

ments become reproducible that we have anything that can properly be called science.

The second basis for a scientific approach to the problem is the fact that we seem to be able to separate out of the infinitely complex mental make-up of individuals a number of independent powers or abilities or aptitudes that can be measured and studied each by itself. This greatly simplifies the problem, but it forces us to be constantly on our guard against unconsciously assuming that the relatively few aptitudes that can as yet be measured are the whole story, or even that we can ever hope to get the whole story by laboratory methods of this kind.

As an example of what we mean by independent abilities or aptitudes, let me describe two very simple tests that were worked out by my friend the engineer as an aid in selecting girls for factory work. The first is what is called a finger dexterity test. It uses an aluminum slab in one end of which are a hundred holes arranged neatly in ten columns and ten rows. In the other end is a shallow tray containing something over three hundred pins, that is little pieces of aluminum wire about an inch long and a sixteenth of an inch thick. The job is to pick up three pins at a time and put them in the first hole, then three more in the second hole, and so on until the hundred holes are filled. With a stop-watch the observer measures how long the subject takes for the job. This simple test has proved very useful in selecting nimble-fingered girls for electric-meter assembly and other hand work on small objects.

There were, however, other sorts of work in the factory, for example, jewel inspection for pivot bearings, that had to be done not with the unaided fingers, but with a pair of tweezers or with some other small tool interposed between the hand and the work. So a slight variation of the test was devised, in which the subject used tweezers to pick up one pin at a time for each of the hundred holes.

The two tests are so nearly identical, involving as they do the same fingers of the same hand, the same pins, practically the same holes, and practically the same job, that it seems almost foolish to use both tests, except perhaps as corroboration each of the other. One would suppose that nearly every one who did one test well would do the other well also, and conversely. Indeed the company had unconsciously assumed this for years, for they had made it a practice to put all newly hired girls on finger work for a year, and then to transfer the best of them to tweezer work as occasion required. But when the thing was tried out in the laboratory, the two aptitudes, finger and tweezer dexterity, were found to be almost wholly independent of each other. Both the best and the worst quarters of a large group of girls tested for finger dexterity would scatter all over the scale on tweezer dexterity; one would be exactly as likely to find a good tweezer operative among the worst finger operatives as among the best. Indeed one stood precisely the same chance of getting one by picking a girl at random from the applicants in the employment office. Possessing or lacking finger dexterity gives practically no indication whatever as to whether a given individual also possesses or lacks tweezer dexterity. Each of the two abilities must be measured separately, and it is pure chance whether any given individual will be better than average at both, or worse than average at both, or good at one and poor at the other. This is what I mean by calling these two abilities independent aptitudes.

Indeed these two aptitudes are so independent as to present one of the somewhat uncommon cases in which striking sex differences emerge under laboratory conditions. Women seem to have distinctly more finger dexterity than men, only about 10 per cent. of a large group of men being, in general, as good as the top quarter of an equally large group of

women. On the other hand, men have more tweezer dexterity than women, only about 15 per cent. of any large group of women being as good as the top quarter of an equally large group of men. That is, women excel whenever the hand does the work; men excel whenever the hand uses a tool to do the work.

Why this should be, what racial inheritance or universal environmental or educational difference is here in evidence, my hearers can guess as well as I can. The facts have, however, an interesting industrial significance. There are in factories many departments where the work is distinctly of the finger dexterity type. In such cases one almost always finds that the management has learned by experience to use women operatives. Similarly, in departments where the use of small tools is characteristic of the job, men operatives are almost invariably used. But occasionally one comes across a department where the work requires a mixture of finger and tool dexterity, where operatives should rank high in both aptitudes. In such cases it will usually be found that the management has been uncertain which type of operative to use, that they have tried at times men, at times women, at times both working side by side. Furthermore, in such cases, one usually finds a higher labor turnover, a higher percentage of rejections by the inspection corps, and a higher record of customer complaints than in other departments of the same plant. All these lessons, learned by experience, find explanation in the facts about finger and tweezer dexterity that have emerged from the laboratory. And all these difficulties can now be minimized by any employer who is ready to make intelligent use of laboratory technique in his employment office.

I have given you a striking example of two abilities that seem closely related and yet prove to be almost wholly independent. Let me now give an example of an opposite sort. Bookkeepers and accountants deal with figures, usually tabulated in columns. A number-checking test has therefore been devised in which two columns of figures are compared, item for item, and checked as the same or different. The job is timed with a stopwatch, and an experimentally determined time penalty is added for each error. This test has been found to work well, both in characterizing people known to be good bookkeepers, who do the test much better on the average than unselected subjects, and in selecting good bookkeeper material for training.

Stenographers and secretaries, on the other hand, deal not with *numbers* that have to be read digit by digit, but with *words* that are read as a whole, a single glance associating a meaning with a group of letters not perceived separately. This ability can be measured by a word-checking test in which the words in two columns are identified as the same or different. One would be inclined to guess that checking figures and reading words are mental processes more different from each other than picking up pins with one's fingers or with tweezers. Nevertheless, exactly the opposite proves to be the case. Both bookkeepers and stenographers do both tests well, and a high or a low score on either test is a strong basis for predicting that the subject will perform correspondingly well or poorly on the other test. One single clerical aptitude enables a person to deal effectively with either number or letter symbols, whereas neither of the dexterities spills over into the other dexterity field.

Perhaps these examples have sufficed to show you what we mean by independent aptitudes, how important they may be in industry, and how useless it is to attempt to guess without careful experimentation what the cross relationships are between various abilities and powers.

But there are also educational advantages that may be expected to flow from studying individuals in the impersonal fashion, and with the constant effort to measure things quantitatively, that are characteristic of science.

For example, one of the chief problems of an educational administrator is the wise selection of his freshman class. American colleges have elaborate admission systems, including lists of subjects that are supposed to constitute adequate preparation, a highly organized system of giving and grading entrance examinations, carefully guarded procedures of certification and jealously maintained standards of admission, and yet our survival rates are often shockingly low. Indeed, it has been said that scarcely a third of those who hopefully enter American engineering schools each fall manage to graduate in due course four years later. At least half of them probably never graduate at all, and in many cases this means not only a waste of time and money but also thwarted ambitions and bitter disillusionment that leave lasting marks on a student's personality and character.

Fortunately, criteria that will help us to recognize impending scholastic disaster when students apply for admission to college are beginning to emerge from the intensive scientific study of human beings that is going on all over the country, so that we can warn and watch and help, even if we can not always dissuade or exclude our weaker students. All these criteria must, of course, be used with great caution; they indicate rather than prove that failure will ensue; in fact, by suggesting the possibility of failure, they sometimes help us and our students to avoid it altogether by special instruction on our side and by enlightened self-discipline on theirs, and so frequently do much good.

Now it happens that the clerical aptitude tests mentioned a moment ago are useful predicters, not only for commercial and business schools, but for all sorts of academic work. There is so much paper and pencil work in any modern educational process that a student blessed with high clerical aptitude has a distinct advantage over one not so endowed.

A still more significant predicter is a vocabulary test that was developed at Harvard some ten or fifteen years ago, and improved and developed at Stevens during the last five or six years. What it apparently measures is the ability to get things out of books, which is, of course, fundamental in any sort of schooling.

And for engineering schools there is another wholly independent aptitude of great importance, namely, the ability to visualize things in three dimensions, to see vividly in one's mind the reality of which a blue print is, to many people, an utterly meaningless portrayal. For this aptitude also several valid tests are now available.

As these and other tests, present and future, enable us to analyze and, in a measure, understand the mental powers of our students, both we and they will do better work, and enjoy it far more abundantly. Perhaps the happiest time in my year is the two summer weeks that we at Stevens devote to our Junior Camp, where, by such means as I have described, we try to help forty or fifty eager young preparatory school boys to study themselves and to decide intelligently whether they should choose an engineering school or an arts college. There we seem somehow to be anticipating the future, and realizing here and now a little of what the science of studying human beings is going to accomplish for mankind.

OUR HIGHWAYS, ARTERIES OF THE NATION

By Professor S. S. STEINBERG

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Of the many developments of the twentieth century, that of highway transportation has been the most profound and far-reaching in its contributions to our national life. Our highway transportation system has not only added immeasurably to the national wealth, but it has enriched the lives of our people socially and culturally. It has provided the foundation upon which has been erected a vast and diversified industrial structure that provides employment for both labor and capital in the manufacture, distribution and servicing of motor vehicles, in road-building and maintenance equipment, in the production and distribution of gasoline, oil and accessories, and in a variety of auxiliary services, including insurance, garages, parking facilities, roadside stands, hotels and many others.

With more than 25 million motor vehicles on our highways, sufficient in number to transport our entire population at one time, the business of highway transportation becomes one of the largest in the country. This is well borne out by some recent statistics. During 1934 the expenditure for new cars and trucks, for gasoline, oil and repair service and for highway taxes totalled eight billion dollars. Of this amount, collections of motor vehicle fees and gasoline taxes alone amounted to one and one quarter billion dollars. This means that motorists paid one out of every eight tax dollars collected. It is estimated that automobile tourists on vacation last year spent almost three billion dollars.

Considering total passenger miles of transportation last year, and excluding waterways, we find that highways carried more than 87 per cent., steam and electric railroads more than 12 per cent. and airplanes less than one per cent. of all passenger travel. There are more than 100,000 buses operating on our highways, and they carry annually two billion passengers, which is equal to one bus ride for every person in the world. The contribution of highways to the advancement of education is evidenced by the consolidation of rural schools, of which there are now more than 23,000 in the United States. These require the use of 70,000 buses which carry more than two and one half million school children each and every day in the school year. To provide this service, school authorities spent more than 48 million dollars last year.

Despite this evidence of the extensive use of our present highway facilities we find our highway system is far from complete. Of our total of more than three million miles of rural highways, only 5 per cent. is hard-surfaced and but 30 per cent. has received any kind of improvement. The remaining 70 per cent. represents more than two million miles of highways which are wholly unimproved. In addition we have about 260,000 miles of city streets much of which is urgently in need of improvement.

These statistics, as well as the personal observation of every motorist, make it evident that we are far from any saturation point so far as improved highways are concerned. There is great need for completing the trunk highway system of the states, for reconstructing and widening inferior roads to better standards, for improving city streets and for building a tremendous mileage of secondary light traffic roads. By-passes and alternate routes are urgently needed in cities

to avoid congestion and to promote convenience of motoring. Better roads and streets mean greater safety, better educational and social opportunities as well as greater economies for agriculture and industry. Improved highways are an investment, never an expense; they are self-liquidating and income-producing. They reduce automobile operating costs by savings in gasoline, tires, depreciation and repairs.

Our highway accident toll has so risen that in the United States alone last year almost 100 persons were killed, on the average, every 24 hours, while one person in every 100 of our population was injured in a highway accident. It is estimated that the burden of property loss and cost of accidents last year exceeded two and one half billion dollars. It is interesting to observe that our total expenditure for highway improvement during the same period was less than one half that amount. Widening, straightening and improving our roads will remove many of the causes of motor vehicle accidents and thereby protect life, limb and property.

One of the great hazards of highway travel, resulting from the fact that railroad building preceded our highway development, is that of railroad grade crossings. In addition to the constant danger they present to life and property, such crossings involve a great economic loss in traffic delays. About 1,500 persons are killed annually and three times as many injured in railroad grade crossing accidents. The new high-speed trains when considered in combination with high-speed vehicular traffic, focus attention on the great need for protecting motorists against the dangers involved, particularly at intersections of highways and main line railroads.

In all we have about 240,000 railroad grade crossings. The great number of these makes prohibitive the cost of completely eliminating them in the near future; for with an average cost of $50,000 for each grade crossing elimination, a project to abolish all crossings would cost twelve billion dollars. At least 30,000 of our crossings are extremely dangerous. At the present rate of progress it will take long after the year 2,000 before even the extremely dangerous crossings will be made safe.

Congress, recognizing the need for grade crossing elimination or for protection by the installation of safety devices, has provided 300 million dollars of emergency relief funds for this purpose to be expended by the state highway departments during the next two years.

While highway transportation has already greatly contributed to the advancement of agriculture, the lack of adequate farm-to-market roads is costing farmers considerable. These roads are generally located outside of the federal and state highway systems and have received scant attention in the past. More than two and one half million farms, or 42 per cent. of all farms, are located on unimproved dirt roads, roads that act as barriers between the farm and the market-place. Because his roads are impassable at certain seasons of the year, the farmer can not take advantage of the best price markets. We find that there are more than five million motor vehicles on farms and that farmers own 26 per cent. of all our trucks. The poor roads penalize the farmer by compelling him to assume the additional operating expense for his vehicle, thereby making the mud tax in wear and tear on farm transportation equipment enormous. Agriculture needs adequate year-around all-weather roads on which it can depend for the economical transportation of commodities.

The development of low cost farm-to-market roads will be of direct economic benefit to the farmer, will remove isolation in agricultural sections, will increase social and educational advantages, will

raise community standards and will make possible better fire protection, medical service and mail delivery in rural areas. Improvement of these local roads at this time will also give relief to unemployment. While the greatest number of unemployed are in the large centers of population, the situation is no less severe in many rural communities.

One of the present trends, which threatens seriously to affect highway development, is the diversion of funds derived from gasoline taxes and motor vehicle fees to purposes other than highway use. Due to the effects of the depression on state finances and as a result of legislative expediency, most of the states have taken large sums from motor vehicle revenues and have applied them to unemployment relief, to schools and to other purposes whose objects are equally worthy but as far removed from the purpose for which the taxes and fees were imposed.

The theory upon which the gasoline tax is based is sound and practical. The reason the gasoline enters the calculation is that it is easier to measure a motorist's use of the highways by the gasoline consumed than it is to measure his mileage. It is essentially a toll for road use that is collected at the gasoline station. When the gasoline tax was first imposed the highway users were promised that the revenue would be utilized for their benefit in highway improvement. As better roads mean lower vehicle operating costs, the motorists appreciated the fairness of the tax. Motorists now contend that diversion of the revenues from these special taxes to general purposes that should be borne equally by all citizens is unfair to highway users as a group.

In 1925 the total of state funds diverted to purposes other than highway improvement exceeded 14 million dollars. In 1933 the practice had become so wide-spread that the states diverted more than 124 million dollars that year or about nine times the amount so used in 1925.

Four states—Minnesota, Missouri, Kansas and Colorado—have adopted constitutional provisions which prevent use of gasoline tax and motor vehicle revenues in those states for other than highway purposes. Last year Congress, in appropriating highway funds to the states, placed itself on record as opposed to the practice of diversion of road funds by refusing to grant full federal aid to those states that do not continue to use at least the amounts that were provided by law for highway purposes at the time of the passage of the act.

It is evident that the highway funds diverted during recent years could have been used effectively in the betterment of our highway system by building a great many miles of modern roads, in eliminating a very large number of our more dangerous railroad grade crossings and in providing work for many thousands of our unemployed.

Experience of the past few years has demonstrated that road-building is one of the best means of providing jobs and at the same time performing a useful public work. The construction and maintenance of highways are operations consisting mainly of labor. Studies by the U. S. Bureau of Public Roads have established the fact that out of every dollar spent for highway construction 80 to 85 cents is ultimately paid to labor, directly or indirectly. Over 10 per cent. of the gainful workers in all occupations earn their livelihood due to our highway transportation system and its allied industries. Only one group, the agricultural, exceeds highway transportation in importance as a provider of jobs.

One of the recent trends in highway development has been advance planning by State Highway Departments of their future road work. These plans are

based upon state-wide traffic and economic surveys and are usually set up for a period of ten years. By anticipating the highway requirements of the next decade, the plan determines the improvements needed on the state highway system and the priority of their construction. The great advantage of advance planning lies in the fact that it establishes a definite and balanced program of road work based upon the anticipated needs and financial ability of the state and replaces the generally unplanned and uneconomical programs of the past, which were dictated largely by expediency and pressure brought from many sources.

Our highways, affecting each of us so vitally, are truly the arteries of the nation; upon them depends our national well-being. They carry to every section of our country the life-blood of agriculture, commerce and industry as well as social and educational advantages not enjoyed by the people of any other nation.

COLLECTING OLD HOUSES

By Dr. LAURENCE VAIL COLEMAN

DIRECTOR OF THE AMERICAN ASSOCIATION OF MUSEUMS, WASHINGTON, D. C.

COLLECTING old houses is the perfect hobby. It takes the collector on trips, and yet never makes him carry a load of specimens, like a geologist, because he never tries to get his collection together in one place. This is convenient, too, because there is nothing to take care of.

The house-collector usually does his work with a car. He goes about the country whenever he has a chance, hunting up places he has heard of, watching for others to turn up, and often having another look at houses he already knows. He carries a camera and he takes notes, for he has a book in his head. He always makes friends with the people who live in the houses he sees, but he needs no introductions. There is brotherhood among people who love old houses, and the owner instantly takes the interested stranger in—going with him first to the attic, where the stranger bumps his head and breaks the ice.

A student of houses soon learns to tell the age of a house within a very few years. He can see the old structure as though its alterations were transparent. He gets to know houses as expressions of their times. If he is less than a student of history, he is not a house-collector, but a camera-snapper. If he does know his houses, a pageant of three centuries is spread before his eyes.

The story of dwellings in America should begin four hundred years ago, but there is nothing left of the very earliest houses. The abundant wood that nature gave to man for his use, she took back again through the work of insects, fire and rot. Therefore, we have not even a trace of Ribaut's Parris Island post, built in 1562 on the coast of South Carolina, or of the post built two years later in Florida by other Huguenots, or of Raleigh's famous Roanoke settlements in North Carolina, or of the outposts built in Maine by the French before the Pilgrims came.

Even our permanent colonies have left nothing to us from their very first years in the early part of the seventeenth century. The original shelters, both South and North, were made of sticks and branches laced together, daubed with mud and covered with thatch. The first cabins were made of poles stuck vertically into the earth around a floor dug half out of a hillside. The first frame houses were of two rooms, sometimes only one. They were half-timbered and

filled in with mud at the start, but later the frame was covered with boards to protect the mud, and then the mud was left out. This was how our present ideas of wood construction came about. Recently, Salem reconstructed a Puritan village, and there alone can we see likenesses of English colonial thatched houses, sod and bark huts, dugouts and construction of palisaded logs.

The oldest remaining house is the Fairbanks house of Dedham, Massachusetts—built in 1636 and amazingly well preserved. Sagged in frame and weathered in surface, with some of the old clay filling still in its walls, it is a document and looks the part. There are many houses from the middle seventeenth century in New England; and some of them, like the Henry Whitfield house in Guilford, Connecticut, are of stone. Rhode Island also has its old stone-enders with enormous fireplaces.

In Virginia, not a single frame house of the seventeenth century is left, but there are some brick houses from the middle of the century. The oldest is thought to be the Thoroughgood house at Lynnhaven. Famous Bacon's Castle is of slightly later date. Old Jamestown has only some foundations and the ruins of a church. Williamsburg, now so splendidly restored, is from the next century for the most part.

Houses of the seventeenth century were built by men who had learned their craft in England; who used medieval methods. Their work in America belonged to the middle ages. The earliest houses are Gothic. In the North, they are small but massive, with ponderous chimneys, steep gabled roofs, and sometimes with overhanging second stories, and casement windows with leaded panes. In the South, the houses are more slender. They have peaked dormers, and chimneys on the outside at each end. In the region of New York and Pennsylvania, nations of continental Europe established colonies and planted other traditions from the middle ages. The Dutch, coming after the Cavaliers of Virginia but before the Puritans of Massachusetts, built compact houses of masonry with white trim and dormer windows. The earliest have steep roofs; those of a little later, gambrel roofs with eaves extending to cover porches, back and front. The old town of Hurley, on the Hudson, still has houses of this kind. New York City once had them, too, but one can hardly find there the haunts of his boyhood, let alone the houses of the Dutch. In Penn's colony, also, masonry was adopted from the start in 1680. There English, German and Welsh colonists made separate settlements. The German stone houses had three stories, full of windows, and dormers and porch hoods. Welsh houses were much the same; but English houses included many of brick, like one still standing in Philadelphia's Fairmount Park.

About the year 1700 the classical style, born of the Renaissance in Europe, appeared in this country. After that, houses were built four-square, with two rooms on either side of a hall. They were higher than in the past, but the roofs were not so steep. And now cornices appeared. This was the beginning of distinguished doorways and mantels with ornamental pilasters and moldings, carved woodwork and modeled ceilings—features that we call colonial and that we now paint white, although colors were much used in those days. This modern whiteness is not surprising. Ghosts are always pallid. We build our Greek memorials now in dead white stone, though Greece made temples alive with color.

The American renaissance was prim at first, but by 1725 it loosened up a little and from that time until the Revolution came the Georgian houses—larger and more elaborate, with more carving around doors and mantels. We got the

ideas from English books, and any good amateur could then design a house. Many Georgian places are still standing along the coast—the Wentworth-Gardner house at Portsmouth, Mount Pleasant in Philadelphia's Colonial Chain of houses, and the Miles Brewton house at Charleston, among the best. The Dutch descendants had their Georgian house, too, like the Van Cortlandt house in New York.

During the years before the Revolution, the eastern towns began overflowing into what was then the West. Along the Appalachians, where those who wanted land could take it, the pioneers built log cabins of the kind we know to-day. They laid logs horizontally, joining them at the corners. This idea came from the Swedes who had settled in Delaware. The early cabins of New England and the South were never like this; they had logs set vertically like cigarettes in a pack.

During the eighteenth century, also, the French were settling scattered posts in the region of Detroit and Vincennes. A few of their houses have survived to show how they too set logs on end and chinked between with mud. Chicago has one of these cabins under a canopy in Jackson Park. The Louisiana region was settled during this same time. Following the lead of Biloxi, New Orleans grew up from a settlement of rude cabins of split cypress boards roofed with cypress bark. Later in the century fires swept everything away, but the Spaniards rebuilt the public square, and the French Creoles replaced dwellings in the old quarter, where there are still half-timbered houses with walls of sun-baked bricks, somewhat later in date but resembling what had gone before. Florida was building in the eighteenth century also, but when French, Spanish and English got through quarreling and various fires had been put out, there was nothing left of the beginnings. In the far Southwest, Spanish priests and soldiers, with Indians to work for them, built the early missions in the eighteenth century, and around them they built adobe cells to live in. The missions still survive.

After the Revolution, there was a classical revival in which Thomas Jefferson himself had an early hand as an amateur architect. By 1820 this revival had turned into the first American fad—building Greek temples. But soon industrialism captured the land, and people were so busy grabbing and exploiting that they stopped paying much attention to their houses. Flats appeared in cities, botchy houses covered with ornaments from the scroll saw and the turning lathe were put together with more haste than taste, and things that looked like packing boxes became the homes of the poor.

Then, after 1860, all sorts of revivals came along, and those who could afford it built anything from a Gothic castle to a mosque—to show who they were. From the French we adopted the mansard roofs, which had been invented to get around the Paris tax collector, who counted floors.

But out of all this in the end came a new and worthy architecture made possible by steel girders and elevators. This is a recent chapter of the story familiar to every one.

There are thousands of houses in every part of the country worthy of being saved because they are old or fine or representative. Some of them are called historic because they have held important people or seen great events. But all houses are really historic because they help to tell the story of America. Hundreds of them, mostly old, have been saved as historic house museums in the care of organizations. These, and many others that still are homes, are in my own collection of houses; and if you want them for yours, I give them to you.

THE WORLD DIGS UP ITS PAST

By Dr. HENRY RUSHTON FAIRCLOUGH

PROFESSOR OF CLASSICAL LITERATURE, EMERITUS, STANFORD UNIVERSITY; FORMERLY EDITOR OF ART AND ARCHAEOLOGY; ANNUAL PROFESSOR AND ACTING DIRECTOR OF THE AMERICAN SCHOOL IN ROME

"ARCHEOLOGY," says Flinders Petrie, "is the latest born of the sciences," and this science, as the same distinguished authority writes, "touches us more closely than any other," being one "which shows what man has been doing in all ages and under all conditions, which reveals his mind, his thoughts, his tastes, his feelings."

As a real science, conducted and controlled by true scientific methods and principles, archeology came into being within the lifetime of the present writer and possibly of many others who are his readers. To be sure, we are deeply indebted to the antiquarians of earlier days, and we should be very ungrateful if we forgot certain great figures of the past, such as Pliny the Roman, Pausanias the Greek, and Petrarch the Italian, all of whom loved to recall the triumphs of earlier civilizations. In the eighteenth century the famous Winckelmann for the first time applied historical principles to the study of ancient art, and he, therefore, is sometimes called the founder of archeological science.

It was in 1763, in the very year of the publication of Winckelmann's "History of Ancient Art," that excavations were begun on the site of the buried Italian city, Pompeii, and it was about twenty-five years earlier that an accidental discovery led to the partial excavation of the lost Herculaneum and to the recovery of so many of the beautiful marbles and bronzes that to-day embellish the great National Museum in Naples.

At the opening of the nineteenth century and during the Napoleonic wars, Lord Elgin carried off from Athens the famous "Marbles," which are to-day the most precious possession of the British Museum; and other important discoveries of Hellenic art were made at this time, in Sicily, Italy and Greece itself, such as that made by a small party of English and Germans of the sculptures in Aegina, which were later restored and set up in the newly erected Glytothek in Munich.

It was still treasure-hunting, though of an enlightened kind, that gave birth to the scientific approach and the scientific method in the field of archeology. The extraordinary story of Heinrich Schliemann is well known. Born in 1822 in a north German village of Mecklenburg, he served as a grocer's apprentice, started as a cabin-boy on a voyage to South America, was shipwrecked and tossed up on the Dutch coast, then found work in Amsterdam, where his industry and ability so commended him to his employers that they sent him as their agent to St. Petersburg. Here he afterwards began business on his own account, and laid the foundations of an enormous fortune. In 1850 he came to California to search for a brother's grave, which he found in Sacramento, and in May, 1851, he had a narrow escape from death in the San Francisco fire of that year. By reason of his presence in this state when California was admitted to the Union, he was proud of being able to claim American citizenship.

It was not until 1868 that Schliemann first set foot in Greece, but he had always nursed a romantic ideal. In childhood his imagination had been fired by a picture which showed Aeneas escaping

with his aged father and his little son from the flames of Troy, and then and there he made up his mind to look some day for the ruins of that famous city. This strange purpose was confirmed a few years later when one day he listened open-mouthed to a tipsy miller as he recited a long passage from the Iliad in Homer's sonorous Greek.

Scornful scholars laughed when in 1870 Schliemann began to dig for Troy in the mound of Hissarlik in Asia Minor. Eager to reach the lowest level, he made his way down in rough, slap-dash fashion, paying little heed to the upper strata, and by 1873 he had laid bare some fortifications and had unearthed a great treasure of gold. Not without reason did he then believe that here was Troy, and here the wealth of King Priam. As a matter of fact, he had dug too deep, and had reached a layer that must have antedated Homer's Troy by several centuries. Even the treasure, rich as it was, could not compare in value with the vast hoard of gold, silver, ivory and other precious objects which Schliemann was to find three years later at Mycenae—a collection since rivalled only by the magnificent contents of Tutankhamen's Tomb, which in 1923 Lord Carnarvon and Howard Carter brought to light in Egypt.

Schliemann's unexpected success was to bear fruit "an hundred-fold." It gave a tremendous impetus to archeological research and, in various lands, scholars who had been contemptuous or incredulous now turned from their loud scoffings to prayerful planning for other investigations, to be conducted, however, on more approved lines. In 1874 the German Institute at Athens was founded and in 1875 began its thorough excavation of Olympia. In 1877 the French started similar work at Delos, to be followed by their splendid excavation of Delphi. In 1879 the British established their Hellenic Society and shortly afterwards began to explore sites in the Peloponnesus. In the same year the Archaeological Institute of America was founded in Boston, and within two years began its first excavation at Assos in Asia Minor.

As to improvement in scientific method, this was well exemplified by one of Schliemann's own co-workers, for in 1891, the year after Schliemann's death, Wilhelm Dörpfeld, his architect, a man still living, who has been an inspiration to several generations of students, began a fresh investigation of the hill of Hissarlik on a more extended scale, and after examining it layer by layer discovered that there had been nine ancient settlements on the site. Of these the sixth corresponded most closely to Mycenae, and had the best claim to be regarded as Homeric. Dörpfeld's work in the Troad, and the excavations at Olympia and Delphi have served as models for all subsequent archeological investigations on a large scale, wherever conducted.

One of the immediate results of Schliemann's success was to focus attention upon the possibilities of research in the prehistoric field, and thus we can understand why, as soon as the island of Crete, as a result of the rebellion of 1897, was freed from the Turkish yoke, archeologists seized the opportunity to excavate in that famous cradle of Greek civilization. The remarkable discoveries made at Knossos by Sir Arthur Evans, followed by the Italians at Phaestos, the British at Palaekastro, and the Americans at Gournià, have entirely revolutionized our knowledge of the remote past of both the Greek world and the whole Mediterranean area.

How far this fresh interest extended at the opening of the twentieth century is well illustrated by the creation, on the part of the British Government, of the Archeological Survey of India. Under this one of our Stanford alumni, David Brainerd Spooner, served as superin-

tendent of the North-West Province, and in this position made a brilliant record. Not only did he fill his new museum at Peshawar with objects illustrative of the influence of Greece and Persia upon Indian art, but he also laid bare the site of a large temple built by a Greek architect for King Kanishka, and then he discovered at the very center of its foundation a crystal casket enclosed in bronze and containing human bones that have been officially recognized by Buddhists throughout the world as relics of Gautama Buddha himself.

In regard to Egypt, it was in 1880 that Sir Flinders Petrie, of London, began his excavations, while our best-known American Egyptologist, Dr. James Henry Breasted, of Chicago, entered on his work in that land in 1894. In Berlin eight years later, when I first met Dr. Breasted, he remarked to me that the history of Egypt was not yet written, though the material was accumulating very rapidly. Since then it is astonishing how much has been learned about that ancient land, and how much both Petrie and Breasted have contributed to our present abundant knowledge.

To-day, however, the center of interest in archeological research has passed from Egypt to Palestine, Mesopotamia and neighboring countries. Sir Flinders Petrie is now working in Syria, and the Oriental Institute, directed by Dr. Breasted, is conducting excavations at Persepolis, the ancient palace-city of Persia.

In Mesopotamia, under the changed conditions since the Great War, research has been carried on with the cooperation of English and American scholars, and two of the oldest cities in the world have thus been explored—Kish, said to be "the first city built after the flood," and Ur of the Chaldees, the birthplace of Abraham. The former was excavated by the Field Museum of Chicago and the University of Oxford; the latter by the British Museum and the University of Pennsylvania. The discoveries include records of the life lived by people between the Tigris and Euphrates six thousand years ago. And, even as I pen these lines, there comes the news that a scientific party from the University of Pennsylvania, digging in the same region, on a site where twenty ancient settlements lie buried one above another, has just reached the level of a town antedating Ur of the Chaldees by some 2,000 years.

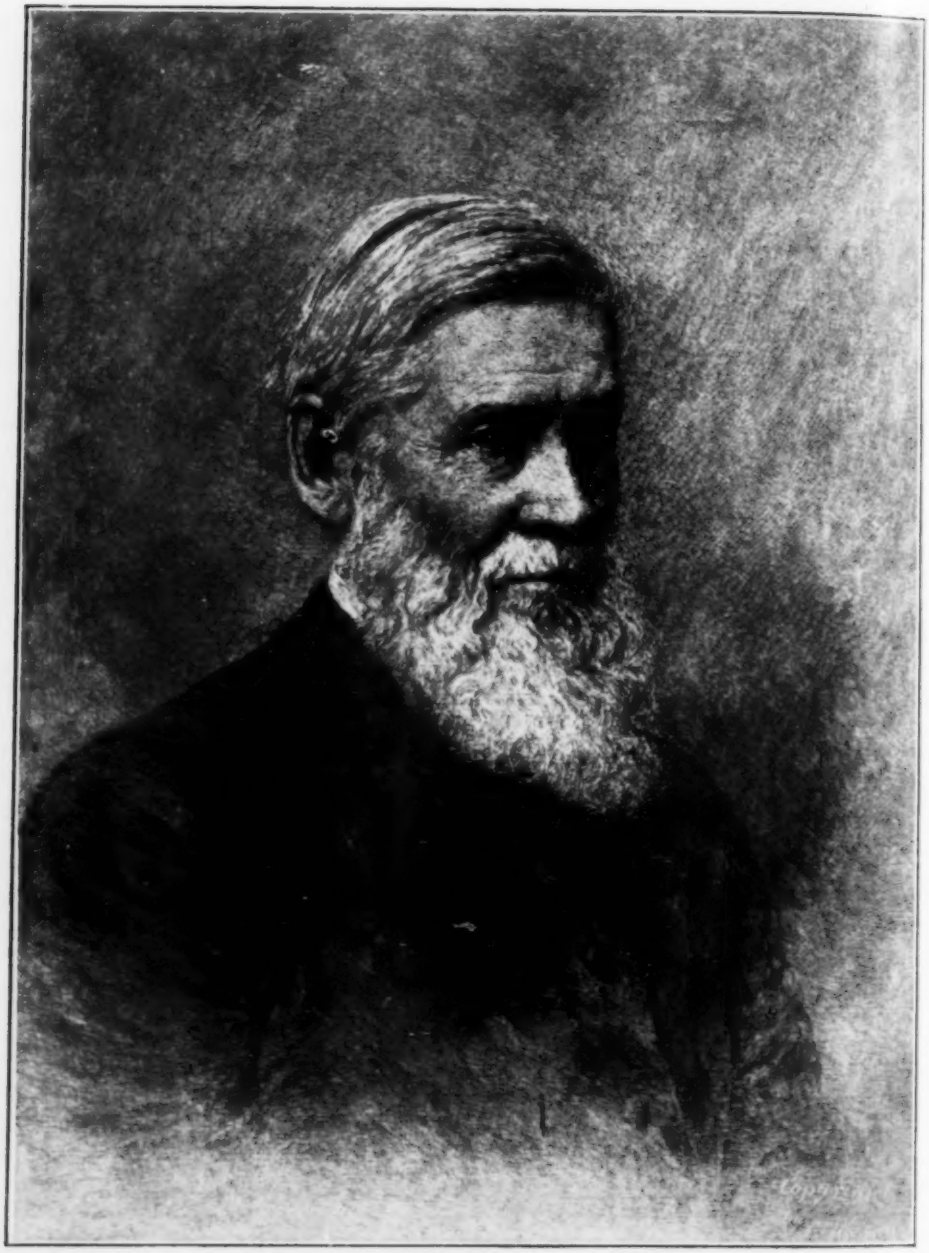
But it is in Palestine that archeologists are most active to-day. They are exploring ancient Biblical sites, such as Mizpah, where our own Dr. Badè, of the Pacific School of Religion, is still at work. And the most outstanding discovery yet made in Palestine is to be credited to another Californian, Theodore D. McCown, son of Dr. C. C. McCown, the present dean of the same school. In the spring of 1932 Mr. McCown, working under the joint auspices of the British School of Archaeology in Jerusalem and the American School of Prehistoric Research, had the great good fortune to find eight complete skeletons of human beings buried in the floors of caves at the foot of Mount Carmel. They are so completely embedded in the limestone breccia that it will take some years of careful work to detach them without injury. Judging from the bones of extinct animals found with them as well as from the rock itself, Sir Arthur Keith refers these skeletons (including a ninth, found by Miss Dorothy Garrod) to a period earlier than that of Neanderthal man in Europe, possibly 100,000 years ago.

These skeletal remains of man long antedate the Stone-Age paintings that have been found on either side of the Pyrenees. The first of these discoveries was made in the Altamira cave in Spain in 1879, and since then more than fifty similar caves in both Spain and France have yielded thousands of specimens of

a skilful pictorial art, which was contemporary with the existence in those countries of the reindeer and the bison, as well as of the mammoth and the woolly rhinoceros, animals now long extinct. These remarkable wall-and-ceiling paintings were produced at a time when man lived wholly by hunting and fishing and before he knew aught of the weaving art, of the building of huts, of the smelting of metals, of the taming of animals or of the tillage of the soil.

Space does not permit me to make more than a brief reference to that field of archeology which to many of us is the most attractive, because it lies, as it were, before our very doors. It is now generally conceded that America was a manless world until human beings passed from Asia across the Behring Strait and thus spread throughout this continent. When such a migration first took place is not known, but Dr. Hrdlička, probably our most outstanding anthropologist, would place the event not more than five or six thousand years ago. The many native cultures that have been developed in America since then include the Pueblo, the Mayan, the Aztec and the Inca, which have left so many interesting and imposing evidences. In the discovery and study of these many of our universities and museums are now engaged, and along with them certain foundations, such as the School of American Research at Sante Fe, New Mexico, one of the latest-born children of the Archaeological Institute of America.

With all the modern facilities for research, no wonder that many of our college students are attracted to the pursuit of archeology, for not only is it the youngest of the sciences, but it is also one of the most fascinating, dealing as it does with the past life of man in all parts of the world from the very infancy of the race.



ASA GRAY

THE PROGRESS OF SCIENCE

BOTANY AT HARVARD UNIVERSITY

A VERY few educational institutions at home and abroad have single separately endowed botanical units, such as herbaria, arboreta and gardens, but Harvard University has the unique distinction of controlling eight separately endowed units within the general field of botany. It is these quasi-independent units that have given the university the outstanding international prestige that it commands in this field of science, for much of the productive work of several of them has been distinctly of international scope.

These separate institutions, all a part of the university, and, to a certain degree, their destinies controlled by it, are independent of each other, yet all are cooperating in botanical research. They have been established over a long term of years, in some cases on the basis of bequests to the university for specified purposes, in other cases due to the interest and ability of individual members of its staff who utilized their own funds for establishing and maintaining activities in which they were interested, or who secured their support from individuals that they interested in their projects. Among the institutions established on the basis of initial endowments are the Bussey Institution, the Arnold Arboretum (in the case of the latter its resources tremendously increased by its first director) and the Atkins Institution. Among those that were actually established by individual members of the university staff are the Gray Herbarium, the Farlow Herbarium and Library, the Harvard Forest and the Botanical Museum. The eighth independent unit, the Botanic Garden, the oldest of all of them, was gradually developed over a long term of years as an adjunct to the teaching of botany.

These units are, to a considerable degree, independent of the teaching activities of the university, yet many of their staff members offer courses and direct graduate work. Supported entirely by the university and independent of the eight separately endowed units is the magnificent Biological Laboratory, wherein is combined in a single Department of Biology the actual teaching and various phases of laboratory research in botany, zoology and general physiology.

Because of the historical development of the independent units there naturally has developed a considerable amount of duplication in equipment, in reference collections and in library facilities. In fact, Harvard University maintains three of the largest, most comprehensive and most valuable botanical libraries in America and three great herbaria, all rich in historical material. Their combined resources in historical reference material are unequalled in America and are exceeded only in a very few of the older institutions in Europe.

The Bussey Institution, originally developed for instruction and research in agriculture, has contributed its quota to the development of the biological sciences in America. Its resources to-day are largely utilized to support fundamental investigations in genetics, work being prosecuted in both the plant and animal fields.

The Gray Herbarium, established and developed by Dr. Asa Gray, America's greatest botanist, represents his life work as an outstanding authority on the North American flora. It officially became the property of the university in 1864 when Dr. Gray presented it to Harvard College, yet he continued to add to it until his death in 1888. Through the efforts of his successors,

THE GRAY HERBARIUM OF HARVARD UNIVERSITY

A ROOM IN THE GRAY HERBARIUM

Sereno Watson and the late Dr. B. L. Robinson, supported by friends of the institution, its resources were greatly increased. Its reference collections now contain approximatley 900,000 sheets, a magnificent library of nearly 30,000 volumes and over 17,000 pamphlets, housed in a specially constructed fireproof building, a model of its kind. As a taxonomic institution, it is the most widely known one of its kind in America and annually attracts numerous students and investigators because of its unique stores of historical material.

The Arnold Arboretum, the most widely known institution of its kind in the world, owes its existence to a bequest from James Arnold which became available to the university in 1872. It had been stipulated that only one third of the income from this fund could be used until the capital had increased to $150,000, so its initial income, until about ten years later, was but about

A POND SCENE IN THE ARNOLD ARBORETUM

$3,000 per year. The magnificent development of the institution, with its 250 acres of diversified plantings, its great library, approximating 43,000 volumes, and its comprehensive reference collections of living and herbarium material, and the commanding position that it occupies in the botanical and horticultural world is due in very large degree to the ability, support, initiative and persistence of its first director, Charles Sprague Sargent. Its material resources have been very materially increased since Sargent's death in 1927 under the leadership of Professor Oakes Ames. In contrast to the Gray Herbarium, as to taxonomic research, its field has been largely in eastern Asia, that of the Gray Herbarium largely North and South America.

The Farlow Library and Herbarium, bequeathed to the university by Professor W. G. Farlow, represents his lifetime's work in assembling a great cryptogamic herbarium and the comprehensive

HEMLOCK HILL IN THE ARBORETUM

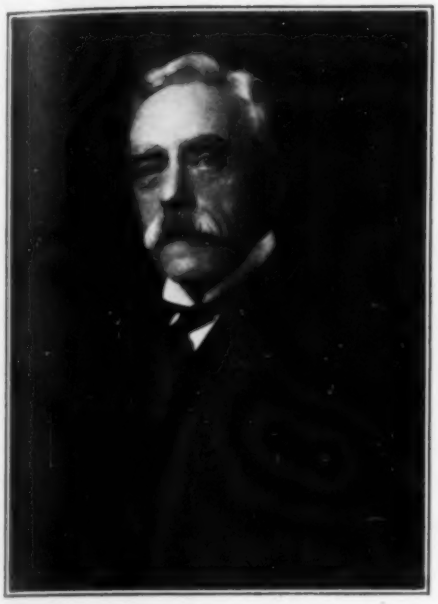
library facilities essential to its proper use. It now contains in excess of 850,000 specimens of fungi, algae, lichens, mosses and scale mosses and is noteworthy for the historical collections acquired from time to time. It is especially rich in type collections. Its library facilities are equally remarkable, somewhat in excess of 30,000 volumes.

The Botanical Museum was established in its present form in 1890, although a so-called museum had been initiated as early as 1858. Its development was the work of Professor G. L. Goodale, continued by Professor Oakes Ames. It is noteworthy for its magnificent Ware collection of glass flowers, the artifacts being the highly skilled, artistic and equally accurate work of Leopold and Rudolph Blaschka. No botanical exhibit in any other existing public or private institution anywhere in the world compares with this in attractiveness and in its appeal to the public, special visitors exceeding 200,000 each year, the number constantly increasing. The museum also contains unique and comprehensive exhibits of the economic products of the plant kingdom, the crude products, displayed in association with the finished products, indicative of their application in the arts, sciences and industry.

The Harvard Forest at Petersham, Mass., comprises approximately 2,500 acres. Its establishment and rather remarkable contributions to the profession of forestry was due to the interest and initiative of the late Professor R. T. Fischer. In its acquirement, development and endowment the objectives were the maintenance of a model forest for the demonstration of various phases of applied forestry without depletion of capital, practical and fundamental investigations in forestry and a great out-of-doors laboratory wherein forestry biology could be effectively studied. Actual instruction in forestry is confined to graduate work.

The Atkins Institution of the Arnold Arboretum at Soledad, Cienfuegos, Cuba, was established by the late Edwin F. Atkins, the work first undertaken there being sugar-cane breeding investigations. Gradually the development took the form of a comprehensive tropical botanical garden, with equipment and living quarters available for visiting biologists. The present area comprises about 300 acres, of which approximately 200 acres are

TROPICAL PLANTS AT THE ATKINS INSTITUTION IN CUBA



W. G. FARLOW

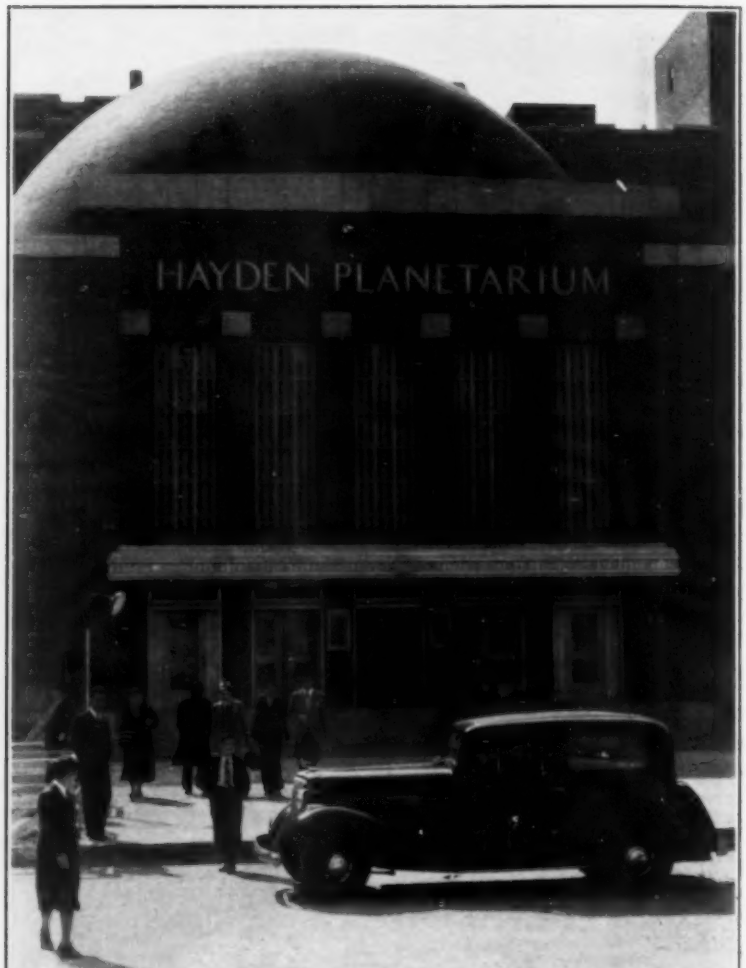
Portrait by John Singer Sargent, 1919
CHARLES SPRAGUE SARGENT

developed and planted. This forms a magnificent tropical base for biological investigations, and it will become increasingly useful in this field as the institution is developed. Its use by graduate students and investigators is increasing rapidly and demands for an opportunity of visiting it and working there exceed the scholarships available for this purpose. It is becoming increasingly evident that all biologists greatly benefit from an opportunity to carry on investigations under tropical conditions, and Harvard University is indeed fortunate in controlling, as it does, this tropical base.

The modern magnificently equipped, commodious Biological Laboratory was constructed in 1931–32. In it is located the Department of Biology, consisting of botany, zoology and general physiology combined, covering various phases of laboratory research, as well as undergraduate and graduate instruction. The construction of this building enabled the university to reorganize its entire biological set-up and to establish a large and very important unit, based on research, comprising all available university groups in the biological field and including various staff members from the several independently endowed units.

The combined resources and output of these numerous units within the general field of botany has resulted in great prestige to Harvard University. It was with the hope that the productive output could be increased and further developed that the position of administrator of botanical collections was recently established at the university. One of the objectives is to further coordinate the work of the independent units, eliminate duplication as far as possible or desirable, encourage cooperation and to develop still further fields of research.

ELMER D. MERRILL
ADMINISTRATOR OF BOTANICAL COLLECTIONS
HARVARD UNIVERSITY


HAYDEN PLANETARIUM

A PLANETARIUM FOR NEW YORK

To the skyscraper city where smoke, haze and bright lights obscure the stars, the Planetarium brings clear skies for every day of the year. All the stars visible to the naked eye, the sun, the moon and the planets may be shown by the Zeiss Projection Instrument recently presented by Charles Hayden to the American Museum of Natural History. Housed in a new wing built with RFC funds, the New York Planetarium was opened to the public on October 3.

The projection planetarium was devised by Carl Zeiss engineers in Jena, and the first was installed in the Deutsches Museum of Munich in 1925. In the ten years since then, twenty-one such planetaria have emanated from the factory in Jena and so far the monopoly of their manufacture remains there. The intricacy of the design of these ingenious machines is an even greater protection than the patents on their many unique features.

Of course countless planetaria had preceded the Zeiss model, but nearly all these represented the sun and the planets as they would appear to an observer in space—not as they are seen in the sky by an observer on the earth. Such devices had shown the solar system by means of models; the new instrument employs a new principle—that of projection.

Hung on a carriage which achieves the maximum of strength with the minimum of structure, the giant stereopticon resembles a dumb-bell. Knobs at each end carry the naked-eye stars, one globe for the northern hemisphere, one for the southern. In all, the 9,000 stars visible to the best eyes under the most favorable conditions are shown by light passed through 32 minutely perforated sheets of copper. These are essentially lantern slides, the projected images of which fit together like the cells of a honeycomb and completely cover the artificial sky dome overhead. So perfect are the images in relative brilliance and position that the illusion of space is unbelievably real and the crispness of the night air is almost sensible beneath the blueness of the night sky. So breathtakingly beautiful are the starry heavens that their first appearance, accompanied by music, never fails to draw a gasp of wonder from the audience.

To produce the rising and setting of the stars, the instrument is driven by motors about its polar axis. Speeds of 10 and 4, 3 and 1 minutes and their combinations (made possible by planetary gearing) may be used for this diurnal motion. To prevent the setting stars from passing across the faces of the audience and over the floor, each lens is equipped with a self-adjusting gravity "eyelid" which automatically shuts off the light of the stars as they reach the horizon.

Rheostatic control of the horizon light as well as that of the sun makes it possible to simulate the dawn with great reality, especially since the sun's projector also carries a diffuse halo.

The planets are represented as they appear in a small telescope so that they may be more easily distinguished from each other and from the stars among which they trace their paths. The apparent annual journey of the planets and the sun may be run through in 4 minutes, 1 minute and 7 seconds, or their combinations. Any daily motion adds its proper increment to the annual motion which, in turn, adds a still smaller progression to the precessional motion. At any of these speeds, the moon provides comic relief with its fleeting phases.

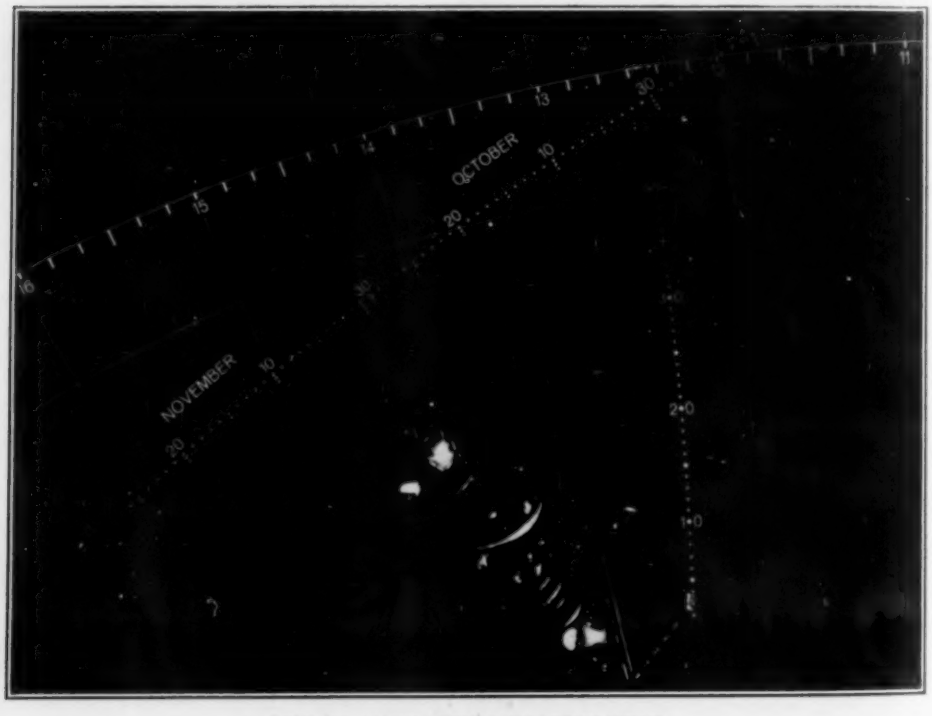
In all the foregoing respects the instrument in the New York Planetarium is very similar to the other Zeiss projectors, but it has several unique features. A "mean Sun," that imaginary timekeeper which does not actually exist, can

appear in the planetarium sky alongside the real sun. The mythological characters of the ancients boldly outline the constellation figures when the new accessory projector is used. The famous Donati's comet arches its filmy tail across the skies in a path identical to that which it followed in 1858 as the motion picture attachment projects its passage. Leo, overhead, showers the surrounding regions with shooting stars as an ingenious device allows light to pass through slits which rotate and fall by means of a spiral shutter.

Up in the polar regions the midnight sun circles near the horizon. For although the machine is anchored in place, by turning on its horizontal axis it can transport its watchers not only in time but also in space. Or perhaps later in the same region, dancing streamers of the northern lights appear and weave their pattern against the black of the arctic night.

All these wonders occur within a room but seventy-five feet in diameter and are repeated frequently for the group of 750 watchers which the chamber will accommodate. The room itself is interesting, for its domed ceiling is a stainless steel shell just one sixteenth of an inch in thickness. It is painted white for reflection of light and perforated with millions of holes for the passage of sound. The perforations, the space between the inner and outer domes and the corklining to the outer dome all help to make an almost echoless chamber.

From the base of the steel sky is cut in silhouette the skyline of New York. Made from panoramic photographs taken in infra-red light just inside Cen-



THE PLANETARIUM INSTRUMENT

WITH THE STARS AND THE SKY MARKERS WHICH IT PROJECTS ABOVE THE ARTIFICIAL NEW YORK SKYLINE.

THE PROJECTION INSTRUMENT AGAINST THE SKYLINE

tral Park near the museum, it shows the museum to the west, the buildings of Fifth Avenue to the east, the trees of the park to the north, and the downtown spires to the south, with the Chrysler Building, Radio City and the Empire State Building prominent among them. The buildings of this skyline are never clouded from view by either haze or bright lights and above them the stars sparkle nightly in a cloudless sky.

In a circular room directly beneath the projection chamber is another type of planetarium in which the solar system is represented in three dimensions. Models of the six planets nearest the sun move about it at their correct relative speeds with their satellites in attendance. The planets' paths are seen against the stars of the zodiac which surround the room in the mythological figures from Bayers "Uranometria" of 1603. The Calendar stone of the Aztecs has been reproduced in the floor of the room in a marble mosaic. This largest Copernican Planetarium in the world is forty feet in diameter and, although it resembles one in Munich, was designed by telescope-maker J. W. Fecker especially for the Hayden Planetarium.

DOROTHY A. BENNETT
THE HAYDEN PLANETARIUM

THE CONTROL OF OYSTER PESTS BY THE UNITED STATES BUREAU OF FISHERIES

BELIEVING that the oyster grower is entitled to protection equally with the farmer, the United States, by a special act of Congress, has appropriated one hundred thousand dollars for the study of marine animals destructive to oysters. The annual losses caused to the oyster growers have amounted to many millions of dollars, and in Florida they have lately caused complete destruction of valuable bottoms and the subsequent loss of jobs to hundreds of people. The U. S. Bureau of Fisheries, under the leadership of Commissioner Frank T. Bell, is now working on this large project on the conservation of the national marine resources in our inshore waters. The results of the work will be of benefit to the thousands of people whose livelihood is entirely dependent on the products of the sea.

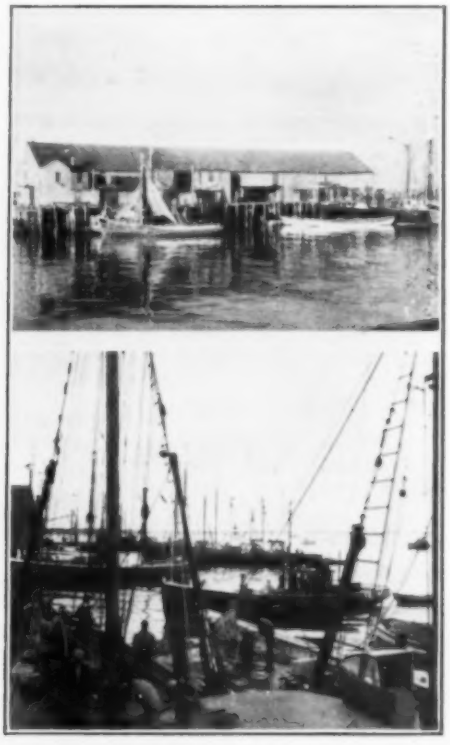
A sudden outburst of a rather innocent-looking planarian, locally called the "leech," which in 1932 destroyed over a thousand acres of oyster-producing bottoms in Apalachicola Bay, Florida, was responsible for the inauguration of this comprehensive research program, which includes also the studies of the distribution, life histories, migrations, destructiveness and methods of control of other oyster pests, namely, the starfish, drills, conchs, boring clams and boring sponge.

Under the direction of Dr. Paul S. Galtsoff the work is being carried on along the whole coastline from Cape Cod to the mouth of the Rio Grande, and is divided into five major projects which, in general, coincide with the distribution of the enemies of the oyster. A large number of zoologists are contributing to the success of the project and all the coastal states are cooperating in the research work.

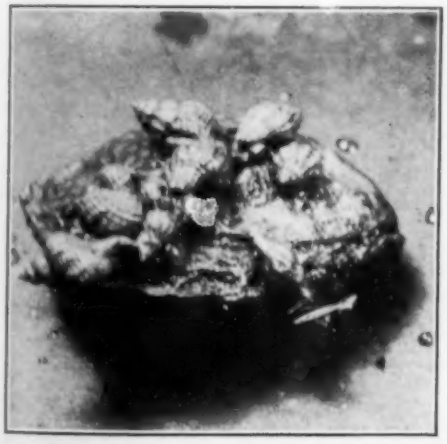
Of all the enemies of the oyster, the control of the "leech" presents the greatest difficulty, for the life history of this organism is unknown to science. In order to carry out this investigation, it became necessary to construct a laboratory at Indian Pass, eighteen miles from Apalachicola, Florida. The work, in charge of Dr. A. S. Pearse, of Duke University, began early in April and so far has produced interesting results, showing the habits of this worm, methods of propagation and its reaction to the environment. Besides the leech, a borer and a boring clam are the important enemies of the oyster in the Gulf of Mexico waters which are being studied by a staff of four scientists stationed at Apalachicola.

In the south Atlantic and middle Atlantic states, the work comprises a study of the tropisms and method of propagation of the two species of snails—Urosalpinx and Eupleura, which destroy oysters by drilling small holes in the oyster shell and sucking the meat. Altogether, sixteen persons are at present engaged in this work carried on under the direction of Dr. H. F. Prytherch, with headquarters at the U. S. Bureau of Fisheries station at Beaufort, North Carolina. The snails have a tendency to climb over any object on the bottom of the sea; this negative geotropism has been utilized for developing a method of trapping, which consists in placing wire bags filled with shells over the oyster bottom. Thanks to the cooperation of the Federal Relief Administration, 150 laborers were assigned to the project and, under the supervision of scientists, are engaged in large-scale field experimentation which provides very interesting data, showing the relationship between the behavior, growth, rate of propagation of the snail and its environment. To show the magnitude of this work, it suffices to mention that during this summer more than ten thousand traps were set in different localities and yielded about three quarters of a million drills. A mass of biological and ecological material has been assembled and is being analyzed. Similar work is being

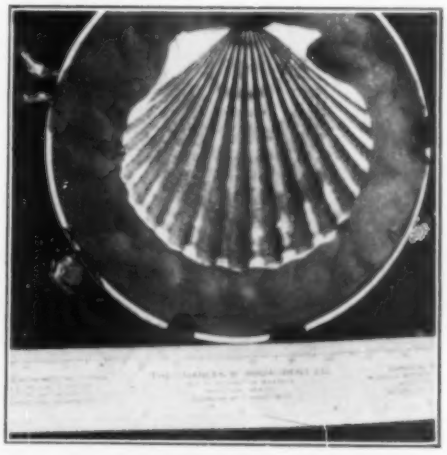
DR. PAUL S. GALTSOFF
DIRECTOR OF THE OYSTER PEST CONTROL PROJECT OF THE UNITED STATES BUREAU OF FISHERIES.



FISHING BOATS AT PROVINCETOWN



DRILLS BORING IN OYSTER SHELL
SO THEY MAY SUCK THE MEAT OF THE OYSTER.



SCALLOP KILLED BY OYSTER DRILL
SEE TWO HOLES IN THE EDGE OF THE SHELL.

THE LABORATORY OF THE UNITED STATES BUREAU OF FISHERIES AT INDIAN PASS, APALACHICOLA, FLORIDA

carried out in Delaware Bay under the direction of Professor Thurlow C. Nelson, of Rutgers University.

The work in the northern states is conducted by Dr. Galtsoff from the U. S. Bureau of Fisheries station at Woods Hole and by Mr. V. L. Loosanoff at the field laboratory at Milford, Connecticut. Eighteen scientists were employed during this past summer to study the life history, behavior, tropisms, development and migration of starfish. Comprehensive surveys, each lasting about three weeks, were made in Long Island Sound, Narragansett Bay and Buzzards Bay. They yielded interesting observations, showing concentrations of this animal in certain regions, its movements in relation to changes in the environment and supplied a large number of data essential for the development of a comprehensive method of control.

Experiments carried out at the shore laboratories were designed to throw some light on the factors controlling the life of the starfish. In order to study their migration, a method has been developed whereby the starfish is stained blue and released in the desired locality. The distinct coloration persists for several weeks and, not being harmful to the organism, permits the identification and tracing of its movements. Over 25,000 stars have been stained already and are under observation in the waters of Long Island Sound. In some of the experiments it has been observed that the starfish moved about twenty-five feet a day.

Carried out on a large and comprehensive scale, the oyster pest control project is yielding valuable biological data upon which sound methods of conservation can be based. It is the first time in the history of marine biology that the zoologists have been called upon to conduct large-scale field experiments that combine the results of field observations with laboratory data. Information gathered so far will be of great value, not only to the immediate problems of the control of pests, but will also contribute to the better understanding of the ecological conditions governing marine life of our inshore waters. Furthermore, at present the project brings relief to a great number of professional biologists who would otherwise have remained unemployed.